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Financing LED solar home systems in developing countries

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ABSTRACT

About 1.4 billion people around the world still do not have access to the regular electricity. It is estimated that roughly 85% of the people without electricity live in rural, semi-urban or remote rural areas of the sub-Saharan Africa and South Asia. Although grid expansion is a vital objective of several developing countries and could be a long-term solution, the remoteness, isolation, low electricity demand of many rural communities, high investment cost of grid expansion make them very unlikely to be reached by the extension of the power grid. Consequently, the off-grid generation systems seem to be the most suited alternative to provide the electricity services to these isolated rural communities.

Solar home systems (SHSs) with Light Emitting Diode (LED) lamps are considered to be cost effective and robust decentralized option for rural electrification. Two financing schemes, fee for service and micro-credit system (ownership), are primarily important for acquiring the SHSs by the rural population. However, high upfront cost of SHSs and absence of payment flexibility is deterring the penetration into larger market of lower-income group rural population. Non-availability of facile finance to rural population at the grass-root level is the major barrier inhibiting the widespread adoption of solar-powered lighting systems. Micro-Finance Institutions (MFIs) can be useful to address the gap between the high initial upfront cost of SHS and low paying capacity of rural households by providing flexible and affordable credit. The One-Stop-Shop Model based on a single micro-energy provider who provides the services of finances, supply of standardized SHSs, and after sale energy services is crucial.

The success of the SHS program depends on the satisfactory technical performance, an adequate financing infrastructure, responsive after sales support, and the extent to which it can fulfill the needs of the end users of having grid quality energy.

Contents

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1. Introduction

About 1.4 billion people (or roughly 22% of the world's population) around the world, most of whom lived in remote areas, still do not have access to the regular electricity [1,2]. The International Energy Agency (IEA) estimates that roughly 85% of the people without electricity live in rural areas in developing countries, mostly in semi-urban or remote rural areas [3]. Fig. 1 shows the population without access to electricity in different regions of the world [4]. Most of these people are found in sub-Saharan Africa and South Asia regions. Africa has the lowest electrification rate of all the regions at 26% of households, resulting 585 million people having no access to electricity [5]. South Asia currently accounts for 42% of the total number of people in the world without access to electricity. The IEA predicts that if no new policy to alleviate energy poverty is introduced, 1.3 billion people (some 16% of the total world population) will be denied electricity most of whom in South Asia and Africa in 2030 [2]. Energy poverty is one of the serious issues that world is facing today as it poses threats to economies, national security, the environment, and public health throughout the world.

The social and economic impacts of providing clean, safe lighting have been well recognized. A lack of reliable lighting access has many fold negative impacts such as:

(i) limiting the productivity of nearly a quarter of the world's population, hindering their ability to carry out basic activities at night or in the early morning. Access to proper lighting has significant positive impact on the productivity and income-generating activity,
(ii) contributing heavily to global carbon emissions and endangering the environment, and
(iii) causing chronic illness due to indoor air pollution by using fuel based lighting and also risk of injury due to the flammable nature of the fuels used [3,4].

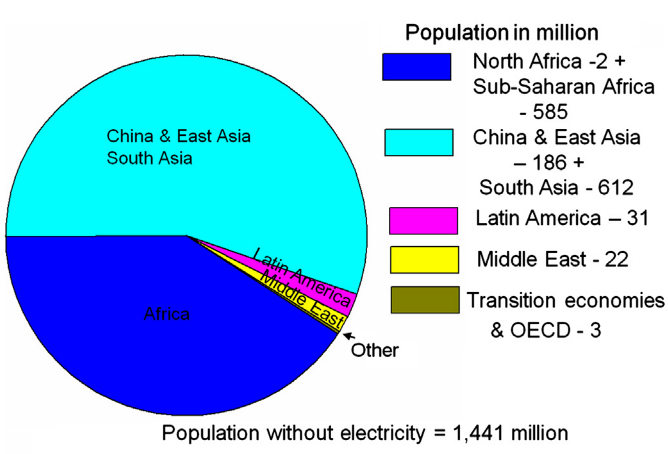


Fig. 1. Population without access to electricity in different regions of the world.

Kids can go to school all day, but are unable to study, read or do home work if they do not have proper light to work with in the evenings. For the literacy development program and nonformal education classes for adults community in the evening time, modern lighting will be useful to provide clean and smoke free light to enable people to read. However due to the slow growth of electrification, a substantial proportion of the world's population is further leaving behind from those with reliable lighting. Without access to modern and sustainable energy services, the poor in developing countries are deprived of opportunities to improve their living standards. Therefore, several Governments, especially in the poorest countries, are at the forefront of providing access of electricity to rural communities.

Indeed, the grid expansion is a vital objective of several developing countries and could be a long-term solution. However, the remoteness, isolation, and low electricity demand of many rural communities make them very unlikely to be reached by the extension of the power grid. Since the grid growth will take decades, many of the benefits of better lighting can and should be captured today through renewable solar light products. Consequently, off-grid generation systems seem to be the most suited to provide electricity services to these isolated rural communities. Several developing countries are implementing various policies for promoting research, development, demonstration, deployment and commercialization of new and renewable sources of energy. Most of these efforts are coordinated only at national levels. Organizations of the United Nations system continue to support the promotion and expansion of new and renewable sources of energy in developing countries [6]. International financial institutions such as World Bank with the assistance from Global Environment Facility (GEF) are playing an important role in mobilizing resources for the promotion of new and renewable energy. Regional development banks such as Inter-American Development Bank, African Development Bank (AfDB), Asian Development Bank (ADB), the Islamic Development Bank, and the German development Bank KfW are also playing a crucial role in promoting new and renewable sources of energy.

With the absence of grid connectivity, kerosene is the most widely used source of lighting, consumed disproportionately particularly by the poor [7]. The percentage of rural households using kerosene as a primary energy source for lighting in developing countries is displayed in Table 1. In fact, earlier World Bank report shows that the average monthly expenditure in rural households of developing countries for kerosene lamp and lead acid battery alone ranges between US$2.30 for low income families, and US$17.60 for upper income families [8]. Furthermore, the recent study shows that the rural households in India

Table 1
Kerosene as an energy source for lighting used by rural households in developing countries.

Country	India	Pakistan	Uganda	Vietnam	Cambodia	Kenya
Rural Households (%)	45	22	91	3.3	60	86

(households among the higher-income levels in the bottom of the pyramid (BoP), earning a monthly income of more than Indian Rupee (INR) 5000) are spending INR 106 per month (INR 1272 per year, US$1 = INR 55.00) on electricity, and those without access to a reliable electricity grid often spend more by buying their electricity from diesel generator-based operators or using car batteries to power small appliances (car batteries cost around INR 3500) [9]. These expenditures are similar to the monthly cost of a solar home system (SHS). Kerosene costs 25–30% of a family's income—globally that amounts to US$36 billion a year. Poor are not using kerosene because it is cheap; they are kept poor in significant part because they must rely on expensive, dirty kerosene. They are paying a lot for kerosene and candles for lighting, but receive only 0.1% of the lighting benefits. The kerosene is affordable and poor can buy a single day's worth in a bottle. Replacing kerosene with a vastly superior 40 Watts peak (Wp) solar home systems (SHSs) would cost only US$300 and provide them not only light, but access to cell-phone charging, fans, computers, and even televisions. However, the high upfront cost of SHSs is deterring the penetration into larger market of lower-income group rural population. Glemarec in his recent article has emphasized the role of public instruments to catalyze the private finance to increase the affordability of clean energy technologies, provide access to financing for the poor, and remove non-economic barriers [10]. Non-availability of facile finance to rural population at the grass-root level is the major barrier inhibiting the widespread adoption of solar-powered lighting systems.

In the present paper, various mechanisms practiced to finance the SHSs at the grass-root level in different regions are discussed. These results are analyzed in the contest to improve the purchase and adaption of SHSs to improve the quality of life of off-grid households. Financing Schemes, fee for service and micro-credit system (ownership) which are primarily contributing to the success of SHS program and important for acquiring it by the rural population are discussed. Free distribution of SHS model is not economically sustainable in the longer term for the poor. In fact, free-given of SHSs from the government project may spoil the possibility of sustainable development of SHS Market and innovations in the field. In the present study, sustainable, flexible and affordable type of financing model, required for the dissemination of SHS lighting to poor population, is discussed. The One-Stop-Shop model based on a single micro-energy provider who provides the services of an MFI or the standardized SHSs at an affordable monthly fee, installation and maintenance, and after sale services is imperative for the success of SHSs program for providing modern lighting energy to rural population.

2. Solar home system (SHS) and LED lighting

Household lighting is a fundamental need, required in the home to extend work and study hours, and allow household tasks and other social activities. The electricity demand in rural regions is mostly dominated by home lighting loads which is insufficient to justify the substantial capital investments required to build electricity generation and transmission infrastructure. Solar photovoltaic (PV) SHSs with Light Emitting Diode (LED) lamps are considered to be cost effective and robust decentralized option for rural electrification. A typical SHS consists of a PV module, battery, charge-controller, and end use appliances. The initial SHS case study results in Sukatani in Indonesia [11], Sri Lanka, the Dominican Republic, and the Philippines had yielded the key elements into popularization of SHSs in developing countries and for further successful initiatives [12]. After these success stories, the World Bank recognized that SHS technology was maturing and commercial markets were developing. In the mid-1990s, the World Bank began supporting PV systems or SHSs, as a low-cost alternative to grid extension to deliver energy for development to households in Africa, Asia, and Latin America [13]. By 1999, the Bank, assisted by grants from the Global Environment Facility (GEF), had invested in several renewable energy projects [14]. The popularity of SHSs prompted the World Bank to supply soft loans beginning in 2003 to non-government organizations (NGOs) or microfinance organizations that invest in SHSs. In recent years, World Bank provided US$117.10 million to Yemen to increase access to electricity of rural households in off-grid areas through implementation of SHSs in the Republic of Yemen (May 2009), US$50.00 million to Argentine Republic for the Renewable Energy in the Rural Market Project including 15,500 SHSs (November 2008), US$4.35 million to Ghana for the Solar PV System to increase access to electricity services project via solar photovoltaic systems to poor rural households in remote regions of Ghana (October 2008), US$160.00 million to establish a sustainable program for expanding access to electricity in rural communities and to support the broad-based economic development and help alleviate poverty in Ethiopia (July 2007), US$18.00 million (GEF) and US$12.00 million (REAP) to Mongolia for the renewable energy and rural electricity access projects and to increase access to electricity and improve reliability of electricity service among the herder population and in off-grid soum centers (December 2006) and US$36.27 million and US$3.75 million(GEF) to Lao PDR to increase access to electricity of rural households in villages of targeted provinces (April 2006) [15].

The World Bank Group provided loans for the energy sector totaling US$13 billion during 2010 in mobilizing resources for the promotion of new and renewable energy [16]. Recently, World Bank approves US$172 million for installing 630,000 SHSs in rural Bangladesh to provide the additional financing to the ongoing Rural Electrification and Renewable Energy Development Project (RERED) [17]. Very recently, World Bank has provided US$5.52 million to Rural and Renewable Energy Agency of Government of Liberia for lighting lives in Liberia [18]. The World Bank estimates that more than 2.5 million SHSs are installed worldwide and over 850,000 units are installed in Africa [3]. In recent years most of the global growth in SHS sales has concentrated on a few Asian countries and the market potential is expanding to African and other countries also.

2.1. 20 W Simple SHS for very low income group

The luminous flux of 100 lm matches a typical lighting requirement for a rural household. A period of 3 h was chosen as it represents a typical time for which light will be daily used. Whereas to meet the Total Energy Access (TEA) minimum standard for lighting, a household must have at least 300 lm of light for a minimum of 4 h per day [19]. A total of 300 lm, equivalent to a 25 W incandescent bulb, can allow sufficient lighting for reading and study, and task lighting in the home.

The objective of the 20 W SHS is to provide electricity to households in remote, isolated rural areas. The kit is designed for the poorest of the poor households in rural areas. A typical 20 W SHS which provides only home lighting to small houses/huts (as displayed in Fig. 2) consists of a PV module, battery, charge-controller, and two 5 W, 12 V DC LED bulbs [20]. The complete lighting kit is shown in Fig. 3. The technical specifications of lighting kit are illustrated in Table 2. The total cost of one complete unit of 20 W SHS including accessories is estimated to be around US$250.00. The 5 W 12 V LED bulb used in the SHS is displayed in Fig. 4. Usually, DC LED bulbs with E26/E27 base used in SHS vary from 3 to 10 W. The kitchen illuminated using 5 W DC LED bulb

provides sufficient illumination to carry out the usual activities as displayed in Fig. 5.

2.2. 150 W SHS for higher income group

For richer populations who use more energy, buying a SHS is to be an economic choice compared to other options such as diesel/kerosene generator or frequent trips to diesel-powered charging stations for borrowing automobile batteries. SHSs are becoming more cost competitive as diesel fuel costs escalate. Solar solutions provide safe light and save travel time to battery charging station. A standard standalone SHS with a solar panel to convert the sun light into electricity and a battery to store that electricity in order to use it when needed is a way to provide power to off-grid remote places. Fig. 6 shows a standalone solar house. Table 3 shows the appliances used and total daily consumption of energy. Details of the appliances used every day and technical data of SHS are depicted in Tables 3 and 4, respectively.



Fig. 2. Typical house of very low income group population in remote rural area.

Considering the energy losses in the system, the power (Wh) needed for daily consumption from the solar panel is =438 Wh/day × 1.3 (energy loss factor in the system), which gives 569.4 Wh/day.

2.2.1. Size of the PV panel

Assuming that the sun energy is available for 4 h a day, the total Wp of PV panel=569.4 Wh/4h=142.35 Wp.

Actual requirement: One PV panel of 12 V 150 Wp or two PV panels of 12 V 80 Wp.

2.2.2. Battery sizing

The battery should be large enough to store sufficient energy to operate the appliances at night and in cloudy days.

Total wattage use=570 Wh per day.

Divide this total Watt-hours per day used by a for battery loss of 0.85=570/0.85=670 Wh.

Divide this number by 0.6 for the depth of discharge of battery=670/0.6=1117 Wh per day.

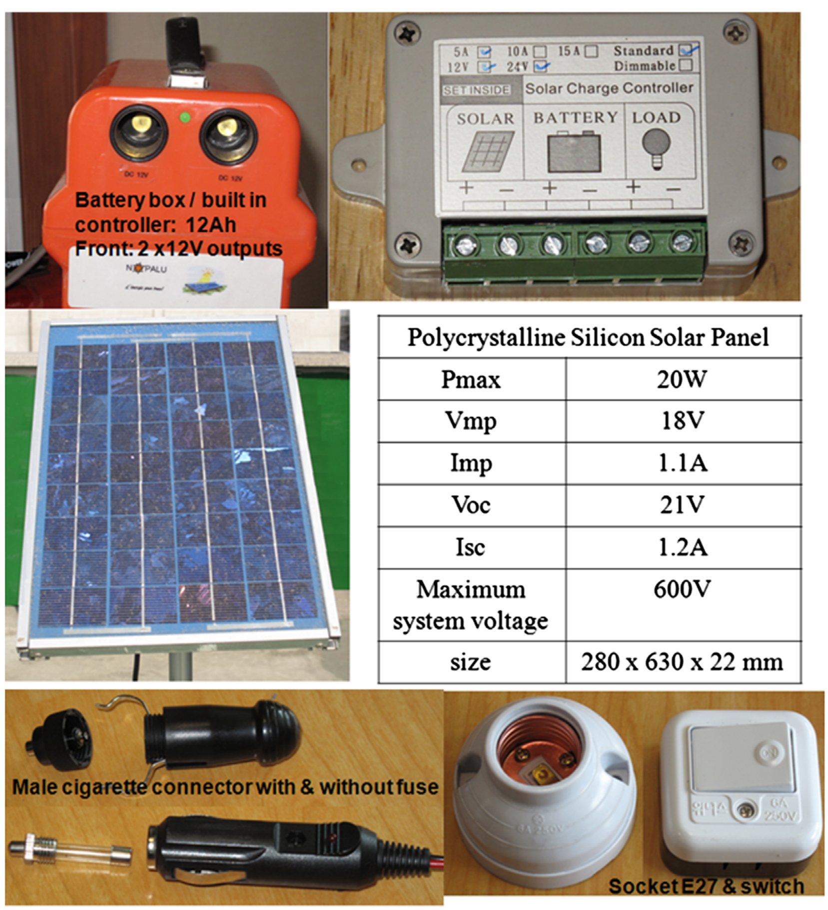


Fig. 3. Individual elements of the 20 W SHS lighting photovoltaic kit.

Table 2
Specifications of solar home lighting system.

Sl. no.	Component	Specifications
1	Solar panel	20 Wp with rain tight junction box, [a]IEC 61215:2005/IEC61646:2008 certification, warranty of 20 years of operation
2	Battery box	12 V/12 Ah deep lead acid sealed cycle battery, IEC 61427: 2005 certification, manufacturing warranty of minimum 2 years
3	Charge controller	12 V/5 A, use pulse with modulation (PWM), High Voltage Disconnect (HVD) 14.3 V and Low Voltage Disconnect (LVD) 11.6 V.
4	LED tube lights or LED bulb	7.2 W/12 V × 2 or 6 W/12 V × 3
5.	Outdoor cable from solar panel to battery box Indoor cable from battery to lamp	18AWG/ 300V/205 °C/sunlight resistant standard multistand wire
6	Accessories	Cigarette lighter male connectors LED Tube clamp, E27 Base for LED bulb, switch, power connectors, cigarette male lighter with USB for cell phone charger, 10 connectors cell phone charger and adapter 12 V

[a] IEC: International Electrotechnical Commission.

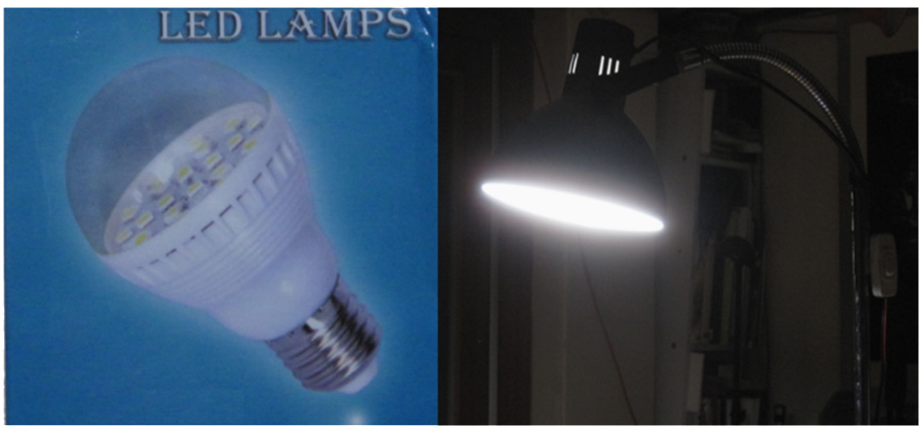


Fig. 4. 5 W, 12 V DC LED bulb.



Fig. 5. Kitchen illuminated using 5 W 12 V (DC) LED bulb.

It comes out to be approximately twice the total wattage use per day (i.e. 570 Wh per day). By considering the nominal battery voltage of 12 V and two days of autonomy (rainy days), the battery capacity: =(1117 Wh/12 V) × 2 = 186 Ah≈200 Ah.

Total ampere-hours battery required is 200 Ah in order to have a longer lifespan of the battery.

So the battery (maintenance free) with 2 days autonomy should be rated 12 V 200 Ah × 1 pc or 12 V 100 Ah × 2 pcs.

2.2.3. *Solar charge controller sizing*

For the fixed voltage charge controller, the High Voltage Disconnect (HVD) is specified as 14.3 ± 0.2 V and Low Voltage Disconnect (LVD) is suggested as 11.6 ± 0.1 V. As per standard practice/technical specification, the maximum current drawn by a charge controller should not exceed 20 mA when no appliances are in use. According to standard practice, the sizing of solar charge controller is to take the short circuit current (I_{sc}) of the PV array, and multiply it by 1.3

PV module specifications:
P_m = 160 Wp
Panel voltage = 12 V
Solar charge controller rating = 160 Wp/12 V = 13 A

Therefore, the solar charge controller should be rated 13 A 12 V. In the system, solar charger controller with 12 V 15 A (or 30 A) × 1 pc is recommended.

2.3. *Concerns of off-grid SHSs users*

Since rural electrification through grid expansion is not possible at many rural habitations due to techno-economic reasons, SHS is the most suitable alternative to provide power to rural

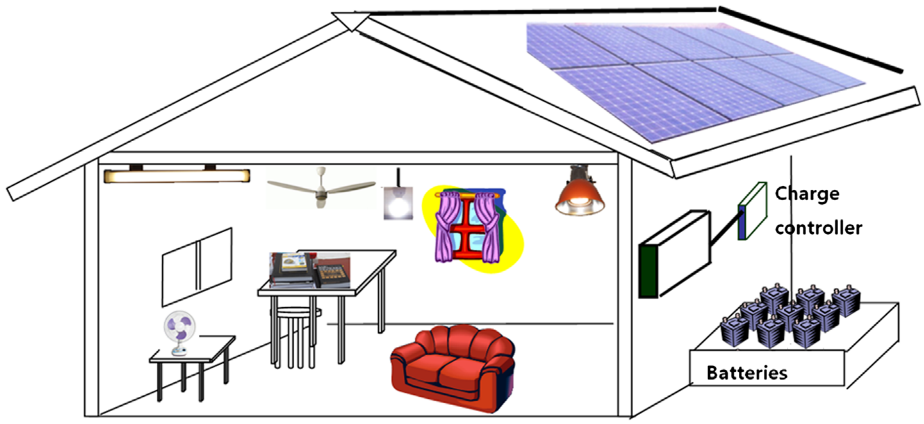


Fig. 6. House in rural areas with solar powered Led lighting and fans.

Table 3
Appliances used and daily consumption of power (Wh).

Sl. no.	Electric appliance	Load reference				
		Power (W)	Quantity	Total power per hour (W)	Work time (hours/day) (h)	Daily consumption (Wh)
1	LED lamp	6	6	36	6	216
2	Table fan (12VDC, 0.8–1 A)	12	1	12	4	48
3	Ceiling fan (12 V DC, 1.2 A)	14.4	1	14.4	10	144
4	Other DC appliances such cell phone charger, radio, low-voltage household appliances such as blenders or sewers	10		10	3	30
	Total			36.4 W/h		438

Table 4
Technical specifications of 150 W solar home lighting system.

Number	Item	Parameter	Qty.
System capacity: 150 W; System voltage: 12 VDC Output voltage: 12VDC			
Technical data			
1	Poly-crystalline solar module	150 Wp or 80 Wp	1 PC or 2 PCS
2	Maintenance-free lead-acid battery	12 V/200 AH or 12 V/100 AH	1 PC or 2 PCS
3	Solar charge controller	12 V 15 A or 12 V 30 A	1 PCS
4	Cables, brackets, other accessories	1 PCS	

households and to improve the quality of life. However, rural populations have several concerns about SHS lighting. These are summarized as following:

(i) *Reliability of SHS power*: Consumers have doubt about the reliability of 24 h × 7 days supply of power through SHS as against the grid supply which is more reliable. Rural inhabitants prefer reliable power supply.
(ii) Batteries of SHS will be costly and difficult to transport in when there will be requirement for replacement. Major concern of villagers is how to deal with their battery once it does not work. Most of villages are in remote areas and sparsely populated. It is hard to reach and provide after-sales services or making available different spares of SHS to villagers scattered in remote areas. Availability and distribution remains a major concern.
(iii) The locals opined that operation and maintenance may be a problem for them as they have neither experience nor have seen any SHS functioning. Further, the disposal of old batteries and taking care of PV panel will also be a problem for them.
(iv) Illumination is the most frequently stated wish regarding the utilization of electric energy. Other favored applications repeatedly mentioned in non-electrified households include the use of fans for air ventilation, listening radios as well as the watching of TVs.

Despite these concerns, villagers are increasingly harnessing the sun to power their houses and wooden huts. The SHS, a standalone system, has become very popular among the rural people. Furthermore, the use of SHS is also continuously increasing due to the solar favorable policies of many developing countries and support from the international institutions in recent days. The brief training of villagers while buying the SHS may help them to address some of their concerns. And surprisingly at places, sometimes villagers themselves are handling the marketing and distribution of SHS. A half-hour training session at the company plus an illustrated guide book is beneficial to turn into a solar installer, at least for his own house. Network of village technicians and an orientation cum training program organized during installation phase for village technicians for preventive maintenance and operation of SHLS will address majority of their concerns.

3. International financial aid and financing SHS

Financing of SHSs to energy poverty eradication and sustainable development is regarded as the main barrier for the dissemination of SHSs. The cash sale of LED SHSs is not considerable in developing countries due to the high upfront costs. Low-income consumers often do not have the initial investment needed to purchase new lighting products. Many villagers find it difficult to switch to the solar energy from conventional kerosene fuel lighting as they cannot afford the upfront investment. Recent report shows that approximately 90% of households lack access to formal

financial services [21], a primary means of acquisition. Local financial institutions (FIs) are often hesitant to lend to consumer due to risk factor of non-receipt of loan. The available financing is often security-based. Furthermore, credits based on the principles of institutional sustainability are hardly affordable for SHS customers. Indeed, access to finance is the biggest hurdle to scaling-up the use of SHSs. A lack of financing options, including limited access to long-term growth capital as well as short term working capital are also the significant barriers to the market growth. So far all SHS programs are relied on subsidies of one sort or another. Therefore, transparent documentation on cost, tariffs and subsidy components and no political motivation in SHS program are also significantly important for the acquisition of the SHS lighting units.

Free SHS program is not economically sustainable in the longer term for the poor. Earlier experiences with the SHS provided with the full subsidy by an international NGO and with detailed training on the importance and need for the maintenance for different components as well as techniques to minor troubleshooting in Zacapa project in Guatemala showed that the 45% of the systems stopped working mainly after 5 years due to minor problems or need for replacements and free SHS model was not feasible [22]. The users were expected to do the maintenance and replacement of components, when needed.

At present, major financial support to the LED SHSs for rural and off-grid populations are coming from the financial institutions such as World Bank, GEF, EU, AfDB, and ADB, as displayed in Fig. 7. In addition, Commercial Banks, National Banks at the National level, and Cooperative Banks, Rural Banks, Rural Farmer Cooperatives, and NGOs at local of respective Governments are also playing imperative role to develop the financial solution to obtain the necessary credit to customers to purchase the solar lighting.

If the targeted population segment does not have access to formal financial services, the informal finance mechanisms could be the good alternative to ensure the financial transactions. The strong liquidity barrier created by the high initial capital costs for SHSs in rural markets with the merge household incomes can be overcome with various instruments like capital subsidies and micro-loans. Microfinance institutions through non-profit social enterprises make available funds to reliable energy suppliers and consumers to finance LED SHS projects.

Some non-profit organizations are also dedicated to bringing renewable energy based lighting systems to off-grid communities. Acumen Fund supports critical services such as water, health, housing, and energy at affordable prices to people earning less than four dollars a day [23]. It uses philanthropic capital to make disciplined investments, including loans or equity (not grants) that yields both financial and social returns. Any financial returns received are recycled into new investments. Acumen Fund has invested in several renewable energy companies [24–27]. Gray Ghost Ventures (GGV) is an impact investment firm dedicated to providing market-based capital solutions to entrepreneurs who are addressing the needs of low-income communities in emerging markets [28]. GGV's focus areas include: microfinance, social venture investment and affordable private schools. E+Co, involved in clean energy investments in developing countries [29], provides business development and investment capital support to create energy businesses that mitigate climate change and reduce poverty while generating financial returns. It has invested in several companies such as: Solar Electric Light Company (SELCO) [30], Lamjung Electricity Development Company (LEDCO) [31], and Kunming Rongxia, China [32].

A new initiative called the Seed Capital Assistance Facility (SCAF) was launched in 2007 for implementation in countries of Asia and Africa [33]. The facility is aimed at helping early stage clean energy enterprises and projects access start-up seed capital from commercial energy investors. This GEF supported Facility is implemented through UNEP, ADB and AfDB.

The Rural Energy Enterprise Development (REED) initiative is a flagship UNEP effort focused on enterprise development and seed financing for clean energy entrepreneurs in developing countries [34]. Till date, about US$ 9 million has been committed to REED programs in five countries of West and Southern Africa, Northeast Brazil and China's Yunnan Province. This 'energy through enterprise' model has been pioneered by the clean energy investor E+Co and advanced by a partnership between UNEP, E+Co, the UN Foundation, Swedish International Development Cooperation Agency (SIDA), Bundesministerium Für Wirtschaftliche Zusammenarbeit (BMZ, German Federal Ministry for Economic Development Cooperation), the W. Alton Jones Foundation and a diverse group of country enterprise development partners. The African Rural Energy Enterprise Development Program (AREED) is the most advanced with debt and equity investments in 32 clean energy enterprises [35]. These investments, ranging in scale from US$12,000 to US$176,000, have seeded businesses in the areas of solar crop drying, sawmill waste charcoal production, efficient cook stove manufacture, wind water pumping, solar water heating, liquefied petroleum gas (LPG) distribution and energy efficiency.

A 4-year US$7.6 million UNEP/bank partnership project is now finishing up which is focused on developing a credit market in Southern India for financing solar home systems [36]. Working through the Indian banking groups Canara Bank and Syndicate

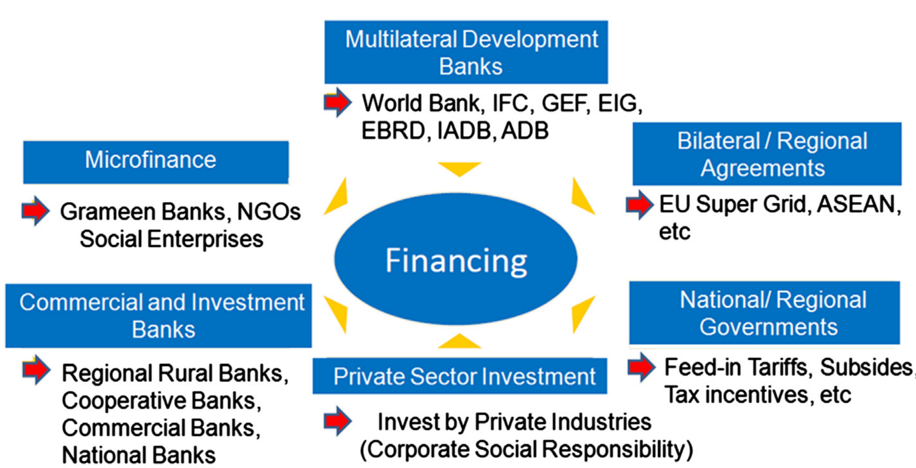


Fig. 7. Financial institutions for providing credit to LED SHS.

Bank, the initiative established two consumer loan programs for solar PV systems that used a form of credit enhancement to bring down the initial financing costs of lending to this sector.

The Brazil Rural Energy Enterprise Development (B-REED) program is developing new energy enterprises in Brazil's northeast regions of Bahia and Alagoas that use clean, efficient and sustainable energy technologies to meet the energy needs of communities and families that do not have them [37]. This program is the joint venture of the UNEP, the UNEP Risoe Centre on Energy, Climate and Sustainable Development (URC), the U.S. based energy investment company E+Co, and its local subsidiary E+Co Brazil.

3.1. Asia

In Asia, about 799 million people live without access to electricity. Some 85% of those people live in rural areas [21]. Rural electrification programs in Asia have adopted several measures such as subsidies on renewable energy technologies (RETs) and SHSs, financing schemes through rural banking system, and microfinance loan from a bank or microfinance institute. In addition, credit facilities to customers are also provided by Commercial Banks, National Banks, Cooperative Banks, etc. Furthermore, favorable role of policy and institutional establishments in providing flexible finances can also play significant role in rural electrification. In Vietnam, 96% of its households had been electrified by 2009, bringing modern power to the Vietnamese people in both urban and rural areas. This high level of electrification is remarkable although Vietnam has a lower average income level than either China or Thailand. Results demonstrate that the action initiated by a high-level political commitment produce the desirable result. If the policy commitment consistent, then achieving goal of energy access to all is not difficult.

3.1.1. Bangladesh

3.1.1.1. Introduction. Bangladesh population is estimated to be about 164 million people in 2011. About 96 million of the population (60%) has no access to electricity [38,39]. More recent study showed that some 58% of rural households in Bangladesh are energy poor, versus 45% that are income poor [40]. Eighty percent of people live in the rural areas, relying on biomass stoves for cooking and kerosene lamps for lighting [41]. Electricity is in deficit as per demand. The total installed capacity of electric power increased from 2350 MW in 1990 to 5823 MW in 2010, with an annual growth rate of 5.17%.

To meet the lighting energy needs, households typically have two major sources: electricity for those who have it and kerosene for those without electricity. The importance of alleviating energy poverty in Bangladesh and the impact on its economy cannot be underestimated. The problems rural people face in obtaining safe, clean, and reliable energy supplies are not minor inconveniences. On the contrary, they represent a significant barrier to rural economic development and social well-being. The rate of electrification is a key to provide lighting. However, extending the national grid to some segments of the population may not prove financially viable due to the physical difficulty in reaching more remote areas and potentially insufficient revenue. Solar PV is considered to be the most suitable option for electrifying rural households.

Bangladesh receives average daily solar irradiation around 4.0–6.5 kWh/m^2 at flat surface, with the maximum radiation in March–April and minimum in December–January [42,43]. Indeed, the abundant sunshine available in Bangladesh makes it a good place to promote solar energy. As a consequence, the SHS has become very popular for lighting rural households in Bangladesh. In-depth study showed that the utilization of SHSs causes positive impacts in the areas of education, health, information, communication, conditions for household work, subjective feeling of security and social activity [44]. The recent results of the analysis in Bangladesh indicate that households with SHS (i) successfully reduce their consumption of kerosene and dependency on rechargeable batteries, with the cost reductions accounting for some 20–30% of monthly expenditures on SHS, (ii) improves the lifestyle with SHS by enjoying its benefits, including electric lighting, watching television, and the ease of mobile phone recharging at home, and (iii) the micro-benefits for each household and the dissemination potential are substantial [45]. The study shows that the household income, kerosene consumption, ownership of rechargeable batteries and number of mobile phones are the key determinants for the adoption of SHS in rural Bangladesh. Furthermore, non-income factors such as kerosene consumption, children study, concerns about indoor pollution, the need for electric lighting and the regional characteristics dummy (reflecting the distance from the local market) also have a significant role in the adaption and size of SHS chosen by households and dissemination of SHS in rural Bangladesh [46].

During last few years, Bangladesh has seen a tremendous growth in SHS with the help of World Bank supported RERED Project administered by the Infrastructure Development Company Limited (IDCOL). The SHS friendly policies of the present government are also encouraging the people to install solar photovoltaic panels in their house roof tops.

3.1.1.2. SHS program and international aid. In 1995, establishment of Renewable Energy Development Agency (REDA) was proposed by the National Energy Policy (NEP) of Government of Bangladesh. The first SHS project in Bangladesh was a demonstration project undertaken in 1995 in Narsingdi district. Rural Electrification Board (REB) implemented this pilot project in a number of river islands in Narsingdi District with the financial support from the French government [47]. The first solar system was installed on 3 August 1996 [48]. The Karimpur, the Natun Bazar and the Alipur charging stations have become operational on 18 January 1997, 3 February 1997 and 6 March 1997, respectively. This pilot project served about 900 households of the island community. The Local Government Engineering Department (LGED) was responsible for the introduction and dissemination of renewable energy in Bangladesh. Following the initial experience from the French-funded pilot project in Narsingdi in 1997, several initiatives for the large-scale promotion of the SHS technology were launched. Encouraged by the success of the REB pilot project in Narsingdi, several NGOs went ahead with their own SHS dissemination programs. On June 1996, Grameen Shakti (GS) came into existence as a renewable energy company. The main program of GS was Solar Photovoltaic Program [49]. First commercial activities with SHSs were initiated by GS in 1997 following the 'cash sale' and 'credit sale' approaches.

In 2002, SHS program through the RERED program of Bangladesh was initiated with International Development Agency (IDA) loan from the World Bank and GEF grant. Since 2003, the World Bank is providing the loan to fund Bangladesh SHS program. Other multinational donor agencies involved in the SHS program include the Asian Development Bank, the Islamic Development Bank, the UNDP and the German Government Development Bank KfW, the Deutsche Gesellschaft für Technische Zusammenarbeit (German Technical Cooperation, GTZ). The international funding was provided through the IDCOL, a non-bank financial institution established by the Government of Bangladesh and is responsible for the implementation of the project. Microcredit programs (MCP) in Bangladesh are implemented by various formal financial institutions (nationalized commercial banks and specialized banks), specialized government organizations and Non-Government Organizations (NGOs).

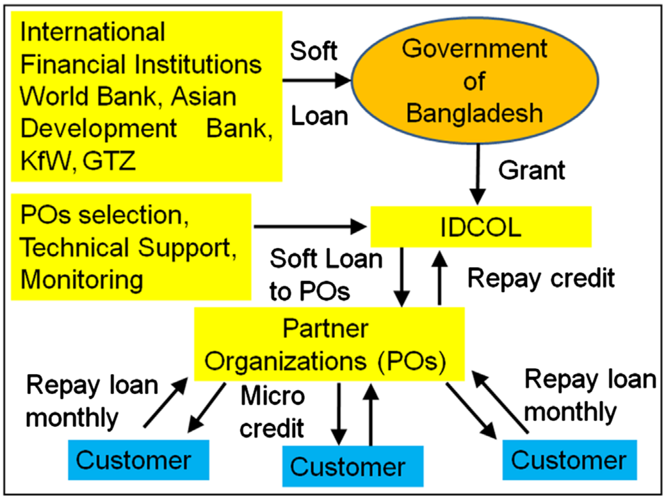


Fig. 8. Project implementation approach of IDCOL program.

IDCOL implements the SHS program through 30 partner organizations (POs). POs of IDCOL (NGOs) have streamlined the marketing, financial and technical models. The project implementation scheme of IDCOL, POs, and customers is displayed in Fig. 8. IDCOL receives fund from the government of Bangladesh, which has itself received soft loans from the World Bank and the ADB with very long tenors. IDCOL provides refinancing facility to the POs and also channels grants to reduce the SHS upfront cost as well as support the institutional development of the POs. In addition, it provides technical, logistic, promotional and training assistance to the POs. It also sets the technical specifications for the solar equipment. Under IDCOL's project, largest number of SHS have been installed in Bangladesh. Further, it has set a goal to install 2.5 million SHSs by 2014 [50,51]. GS, Sister Organization of Grameen Bank, is the major NGO engaged in renewable energy and has installed more than 500,000 SHS systems cumulatively as of year-end 2010 and hope to reach a million by 2013 [52]. Reports show that around 645,033 total SHSs in off-grid households of rural Bangladesh were installed from 1996 to 2010 [53,54].

3.1.1.3. Financing models. During last few years, Bangladesh has seen a tremendous growth in SHS with the help of World Bank supported RERED Project administered by IDCOL. This growth was driven by (i) the motivation to improve lifestyle, (ii) the existence of infrastructure of microfinance institutions; (iii) the clean energy provided by the solar PV over kerosene; (iv) the support of domestic and international institutions; and (v) the word of mouth. Furthermore, the SHS friendly policies of the present government are also encouraging the people to install solar photovoltaic panels in their house roof tops.

Two types of payment schemes for the use of SHS in rural Bangladesh are: (i) fee for service model executed by the REB, and (ii) ownership model (or micro-credit system) which is handled by IDCOL through its POs [55]. In fee for service model, the PV system remains at the ownership of government while the permanent ownership model through micro-credit system is more popular where the land is separated from main-land by a lot of rivers [56] as displayed in Fig. 9. Fee for service model is popular in some areas of Bangladesh.

Typically SHSs in the range of 20–150 Wp sold in Bangladesh are listed in Table 5 [56,57]. Prices varies from 15,000 to 79,000 Taka (Tk.) (US$217.39–1144.92), respectively. The range of SHS unit cost (displayed in Table 5) is well above the average monthly household income in 2010 which is estimated at Tk. 9648 (US $139.82) in rural area [58].

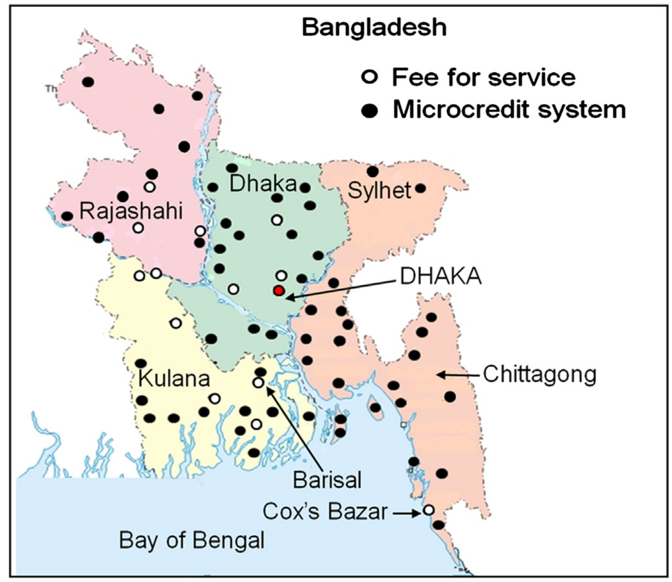


Fig. 9. Fee to service and microcredit models SHS installations in Bangladesh.

3.1.1.3.1. Fee for service model: Rural Electrification Board (REB). The REB is tasked with providing financial support, technical oversight, and long-term direction to the rural electrification program in Bangladesh. The fee-for-service model, which is offered by the REB, Bangladesh charges households a fixed monthly fee to use the SHS installed on their roofs [59]. Main objective of the project is to provide SHSs to remote and isolated rural areas, islands, coastal and hilly areas, and other inaccessible parts of the country where possibility of running grid line is non-permeable because of financial and technical limitations due to the scattering of households in the rural areas and low consumer density. The REB has installed 12,000 SHS under World Bank financed RERED Program from 2003 to 2009 [60,61]. About 80,000 people have been benefited of electricity by the implementation of the project. Although, the institutional constraints has limited the SHS deployment and also undermined after sales service, causing many systems to go into disrepair, the REB is considering a plan to provide 25,000 SHSs to consumers till 2014.

It was intended that this fee would also make provision for maintenance and battery replacement costs. Such an approach can really only work where there is a substantial injection of early working capital. The modest income from fees of this level is inadequate to support the fundamental overheads that such an operation requires where customers are far from major centers with poor access and often limited communications. The fact that the systems are not owned by householders has also led to issues around the security of the systems, tampering with components and/or overuse and a reluctance to meet monthly fees.

The fee for service model is more popular in some regions of Bangladesh [56]. People hope that the national grid is going to expand in these regions in future. When the grid current will be available to users, the SHS will become a burden to them. However, achieving 100% grid electrification will be a difficult task because Bangladesh is a low-lying delta crisscrossed by hundreds of rivers.

3.1.1.3.2. Ownership model-—micro-credit system. The ownership model, which uses microfinance to sell SHS to rural households under the execution of IDCOL, has been highly successful. The IDCOL is tasked to execute the national solar program through its POs. IDCOL offers soft loans of 10-year maturity, with a 2-year grace period, at 6–8% per annum interest to its POs. The loan amount (refinancing) is limited to 80% of the loan given to the households or US$230 per system, whichever is lower. Usually,

Table 5
Price list of SHS packages in GS project. A conversion rate of 1 US$=69 Tk. is used here.

Sl. no.	Grameen Shakti's Solar Home System			
	Capacity (Wp)	**Components**	**Appliances**	**Total price (Tk.)**
1	10	10 Wp solar panel, 18 Ah industrial battery	5 W CFL Lamp, LED Lamp × 2	9500 (US$140)
2	20	20 Wp solar panel, 23 Ah industrial battery	7 W CFL lamp × 1, LED × 3	13,500 (US$199)
3	40	40 Wp solar panel, 55 Ah industrial battery	6 W Lamp × 3, B/W TV	22,500 (US$328)
4	**50**	**50 Wp solar panel, 80 Ah industrial battery**	**6 W Lamp × 4, B/W TV**	**28,000 (US$408)**
5	65	65 Wp solar panel, 100 Ah industrial battery	6 W Lamp × 6, B/W TV	34,000 (US$496)
6	85	85 Wp solar panel, 130 Ah industrial battery	6 W Lamp × 7 17" B/W TV	42,500 (US$620)
7	120	120 Wp solar panel, 100 Ah industrial batteries × 2	6 W Lamp × 10 17″–20″ B/W TV	65,000 (US$948)
8	130	130 Wp solar panel, 100 Ah industrial batteries × 2	6 W Lamp × 11, black and white TV with 17–20″ × 1	68,000 (US$991)

Table 6
Financing scheme of the IDCOL.

Financing by IDCOL to PO	Customer financing by PO
• SHS cost: Tk. 30,000 (US$435) • Down payment (15%): Tk. 4500 (US$65) • Buy down grant A: Tk. 3450 (US$50) (subsidy to households) • Credit to Customer: Tk. 22,050 (US$320) • Refinancing (IDCOL): Tk. 17,640 (US$255.652) (80% of the customer loan) • PO investment (20%): Tk. 4410 (US$64.35) • Institutional Development grant B: Tk. 690 (US$10) (to PO to extend credit to households/hiring staff/ training personnel) (Grants A+B to lower the selling cost)	• Loan to the Household: Tk. 22,050 (US$320) • Down payment (15%): Tk. 4500 (US$65) • SHS price: Tk. 26,550 (US$385) • Loan amount: Tk. 22,050 (US$ 320) • Loan duration: 3 years • Interest (12% flat pa): Tk. 7938 (US$115.04) • Total household payment: Tk. 29,988 (US$435.04) • Replay credit to IDCOL: Tk. 20,815.2 (US$301.67) • Monthly installment: Tk. 833.00 (US$12.08)

IDCOL does not require any collateral or security for the loan, except for a lien created on the project accounts. The POs are responsible for the maintenance of the systems during the 3 years of loan duration after which additional warranty may be purchased by the customer.

Financial scheme: Under the financing program, the process to be followed by POs is as following:

(1) Clients make the required down payment.
(2) POs enter into a sale/lease agreement (provisions of which are approved by IDCOL), install the system (mostly on credit) and make electronic disbursement request to IDCOL for refinance and grants, as applicable.
(3) After in-house checking, IDCOL conducts physical verification of the SHS installed.
(4) IDCOL releases grants and refinance amount only if the inspection result is satisfactory.
(5) IDCOL makes the disbursement within 21 days from the receipt of disbursement request.
(6) This mechanism implies that POs need to mobilize other sources of funding to purchase and install SHS before IDCOL releases the funding.
(7) A standard loan agreement with the end user has to be signed, including the service fee to be charged over the repayment period.

Microcredit to customer:

(i) Minimum 20% down payment from the client.
(ii) The loan tenor varies from 1 to 5 years, usually 2–3 years.
(iii) Interest rate varies from 12% to 15% per annum on declining balance method and from 10% to 15% per annum on equal principal payment method.
(iv) In all the instances, the repayment frequency is monthly.

Financing from IDCOL to POs and POs to customer is depicted in Table 6 [62]. Grants A and B have been provided as incentives to reduce the selling cost of the SHS. The repayment of the loan is monitored to minimize the financial risk of IDCOL. More than 97% overall collection efficiency is achieved by POs in this system. This scheme has been successful since IDCOL has a regulatory role for quality control and financial risk minimization. The hardware used is certified by the IDCOL. Only solar PV module and other appliances approved under the IDCOL SHS Program are qualified for the credit. This minimizes the malfunctioning of SHS unit due to poor technical standard followed by some suppliers and also to gain the trust of rural households in SHS lighting technology [63]. Poor quality products erode the consumer confidence. The IDCOL certification ensures that only standard SHS system will be delivered to the customers and also helpful to win the trust of the rural households in SHS lighting technology.

3.1.1.4. Micro-financing scheme of Grameen Bank. Grameen Bank has demonstrated that the poor are credit worthy and has made micro-credit a global movement. They have also shown that renewable energy technologies are not too expensive for the rural people. Grameen Bank plays dominant role in microcredit financial market in Bangladesh. Service charge on credit varies from 10% to 20% at flat method of collection. People can take out a collateral-free microfinance loan from the Bank or microfinance institute to buy SHS directly [50,64,65].

(i) For marketing the first 100 units, following options are available. 50 Wp SHS per unit costs around Tk. 20,000.

Option 1: Total amount to be paid on installation of the system.

Option 2: Total amount to be repaid in 5 years in monthly installments of Tk. 300, with a down payment of Tk. 5000.

Option 3: To be repaid in monthly installment of Tk. 400, or in weekly installments of Tk. 93.

(ii) Single 50 Wp SHS costs Tk. 24,000.
  (a) Initial deposit: 15–25% of the total cost.
  (b) Outstanding loan: 2–3 years loan of equal monthly installments.

The success of SHS program of Grameen Bank is attributed to its innovative business model. The key drivers include micro-credit based financial model, vast operational network, cost-effective production, Grameen Technology Centers (GTCs), micro-utility systems, and focus on after sales services [66].

3.1.1.5. Financing scheme of Bright Green Energy Foundation (BGEF). The government through the IDCOL and donor community are supporting Bright Green Energy Foundation SHS finance model. Around 11, 000 SHSs have been installed by the foundation since 2002 [67,68]. The financing scheme is as follows:

(i) *First stage*: Credit for 6 months with 50% down payment.
(ii) *Second stage*: Credit for 2 years with 25% down payment.
(iii) *Present stage*: Credit for 3 years with 15% down payment.

3.1.1.6. Acceptance and success of SHS. The unit cost of small capacity SHSs (10–20 Wp) varies in the range of Tk. 6500–13,000 and the monthly installment fee is about Tk. 175–350. Households' average fuel (i.e. kerosene) requirement was found to be 5–6 l per month and used to spend Tk. 200–250 on an average in each month as fuel cost. The kerosene fuel monthly expenditure is similar to monthly installment of small SHS. Further, the cost of kerosene or the charging cost of battery is quite high and SHS can compete with them in this particular field [69]. Therefore customer who has income of Tk. 3000–4000 per month can afford to buy a small SHS in credit [70], even though his income is well below the average monthly household income at Tk. 9648 in rural area [58]. A 50 Wp SHS unit is most popular and widely adopted by rural households (Table 5) since the credit is easily available from the IDCOL without requiring any collateral or security for the loan. In fact, more flexible financing to reach any sizable number of households may further enhance the market share and popularity of SHSs.

As of March 2012, 1.4 million SHSs have been installed in Bangladesh, with electricity generation of up to 65%. Five million rural people living in off-grid areas are benefited and light up their houses. IDCOL now has set a new target to finance 2.5 million SHSs (cumulative) by 2014 [71]. By February 2012, GS has installed nearly 750,657 SHS cumulatively. The division wise cumulative installations of SHSs are displaced in Table 7.

Table 7
Division wise cumulative installations of SHSs as on March 2012.

Division	Number of SHSs installed
Barisal	245,185
Chittagong	257,578
Dhaka	346,161
Khulna	146,388
Rajshahi	185,267
Sylhet	140,386
Total	1,320,965

SHSs and the SHS program developed and implemented in Bangladesh has been highly successful, with very large numbers of rural households now participating in the program. Indeed, the evidence of success can be evaluated by considering the cumulative installations of SHSs as reflected in Table 7. Every year number of customers is increasing. The popularity of SHS is evident considering more than 7500 SHS being installed per day in Bangladesh.

3.1.1.7. Conclusions. Bangladesh has developed an economically viable solution for providing electricity to rural areas where the national grid is difficult or expensive to extend. SHS units are well received by small entrepreneurs for lighting and extending their business hours. Street eatery owner thinks that LED light is the best investment he ever made. Extended business hours in the evenings times increases the earnings by double. However, some customers using SHS only for lighting purpose feel that repayment amount is burden for them. NGOs are charging a huge amount of money including interest from the consumers. More flexible financing may be required to lessen their burden and light the households of rural poor. The SHS program in Bangladesh is considered to be one of the most successful of its kind in the world, bringing power to rural areas where grid electricity supply is neither available nor expected in the medium term. Since 1996, penetration of SHSs increased rapidly, mainly due to the flexible financing policies of Government on credit to rural households through its extensive network. Micro-credit organizations and microfinance are mainly responsible for the success of SHS in Bangladesh. In conclusion, the growth and success of SHS program is driven by (i) the strong motivation of the rural population to improve the lifestyle, (ii) the existence of infrastructure of microfinance institutions, (iii) making available facile credit for SHS by Government, and (iv) the support of domestic and international institutions. The future looks promising for the SHS program, as the World Bank has recently allocated additional credit funds to it.

3.1.2. India

3.1.2.1. Introduction. About 56% of India's population has access to electricity nationwide, and 44% in rural areas, with 289 million rural people do not have access to the energy needed for lighting according to IEA report [72]. Recent census report shows that the 31% of households nationwide and 43% of rural households still use kerosene to light their houses in India [73]. About 0.4% of households use solar energy for lighting and 0.5% of households use no lighting. The total number of households using kerosene as main lighting source and no lighting in rural India is estimated to be 73.326 million (72,434,602 (kerosene)+892,215 (no light)) as displayed in Fig. 10 and Table 8 [73] while in urban India this figure is about 5.362 million (5,126,285 (kerosene)+236,597 (no light)). It is presumed that all household using kerosene as lighting source can afford to have SHS. With this assumption, the estimated potential of SHS in rural India is about 72.434 million. The finance required to reach about 72 million rural households with US$250 loans (per solar kit) is about US $18,000 million. Earlier, the SHS sector's potential market value for India's rural population segment was estimated to be INR 1.26 billion (US$27.39 million) per year [74].

3.1.2.2. Financing of SHSs. The earlier approach of the government of India (GOI) to address the issue of rural electrification focused on extending the electricity grid fails to attend the real needs of poor people and is too expensive [75]. It was recommended to provide micro-credit and consulting to rural population for the promotion of off-grid renewable energy technologies (RETs). The backbone of these policies was to empower the poor and allow them to use energy in a sustainable fashion, breaking the cycle of poverty that has traditionally made them dependent on the

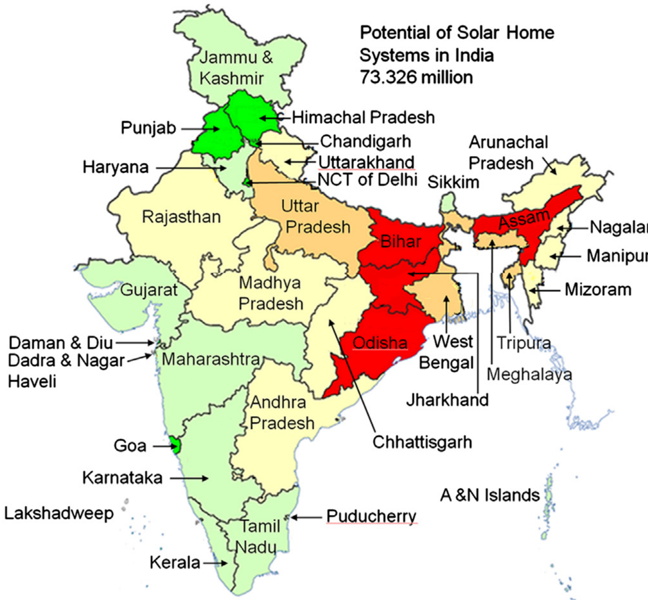


Fig. 10. Estimated potential of solar home systems in rural India (Census, India, 2011).

Table 8
Total number of Households in rural India using kerosene as lighting source or no lighting source (Census, India 2011).

States	Use kerosene as lighting source	No lighting source
Jammu & Kashmir	188,737	38,945
Himachal Pradesh	39,316	1310
Punjab	96,153	29,840
Chandigarh	162	6
Uttarakhand	203,702	4214
Haryana	335,163	14,830
NCT of Delhi	1107	158
Rajasthan	3,729,712	94,903
Uttar Pradesh	1,91,06,303	25,475
Bihar	1,49,63,430	16,926
Sikkim	8036	554
Arunachal Pradesh	46,190	27,401
Nagaland	60,116	4273
Manipur	108,112	2350
Mizoram	28,211	524
Tripura	229,132	2431
Meghalaya	193,788	3799
Assam	3,783,685	10,749
West Bengal	7,928,533	54,868
Jharkhand	3,111,480	00
Odisha	5,114,439	89,584
Chhattisgarh	1,236,319	13,152
Madhya Pradesh	4,549,047	22,244
Gujarat	865,971	94,715
Daman & Diu	191	25
Dadra & Nagar Haveli	2691	212
Maharashtra	3,110,979	169,216
Andhra Pradesh	1,310,660	71,231
Karnataka	967,296	39,320
Goa	4238	748
Lakshadweep	5	00
Kerala	303,079	00
Tamil Nadu	793,803	57,383
Puducherry	3424	475
A &N Islands	11,392	354
Total	72,434,602	892,215

subsidized extension of the central grid and hand-outs from NGOs. Therefore, frantic efforts are being made to improve the quality of life for rural poor by providing the sustainable and clean lighting. In recent days, there is also a growing demand for SHS from grid-connected households which experience significant power outages.

3.1.2.2.1. NABARD and MNRE financing scheme. GOI announced in its solar mission a target of generating 22 GW (20 GW grid-connected+2 GW off-grid) of electricity from solar energy by 2022 [76]. India had 10.2 MW grid connected photovoltaic systems and 2.5 MW stand-alone systems as in March 2010 [77]. In addition, the National Solar Mission also formulates the deployment targets of 20 million SHSs by 2022. The major thrust of the solar mission is to improve grid-connected and off-grid capacity of PV solar energy. The Ministry of New and Renewable Energy (MNRE) in a policy paper on “strategic plan for new and renewable energy sector for 2011–2017” has set a target to cover about 1000 villages from solar power up to 2022 [78]. This is in addition to cover 20 million households with solar lights. However, it is opined that after achieving the 100% rural electrification and reliable electricity supply through the grid in India by 2019, households may no longer buy SHS [79].

Recently in 2011, MNRE has introduced a subsidy linked credit scheme for off-grid SHSs and decentralized applications to promote commercial marketing of solar energy systems and devices by extending financial incentives in the form of capital and interest subsidy on loans availed from financial institutions by the target clientele [80,81]. National Bank for Agriculture and Rural Development (NABARD) has issued a circular to Commercial Banks/ Regional Rural Banks to enable the Banking system to avail of the financial resources including the subsidies on behalf of their borrowers to promote off-grid applications of solar energy. For general areas the Central Financial Assistance (CFA) would be 30% limited to INR 81 per Wp (with battery back-up) and INR 57 for systems (without storage battery). For special category states/ North-East states the CFA would be 90% limited to INR 243 per Wp (with battery back-up) and INR 171 (without battery backup). Table 9 shows the financial assistance on various lighting systems. The total cost, the maximum capital subsidy and the maximum eligible quantum of subsidized loan have been worked out on the basis of the benchmark cost of INR 300 per Wp for 2010–2011 prescribed by MNRE. The salient features of the financing scheme are listed in Table 10.

3.1.2.2.2. NGOs financing scheme. Various financial institutions including NGOs have initiated their financing schemes for SHS systems. Many companies in India have started to tackle this market successfully. Since 1995, SELCO India has helped over 110,000 rural households and small businesses install solar electricity into their homes or workplaces and plan to increase the cumulative installations of SHS to 200,000 units by 2013 [82]. About 669,805 SHS units have been installed by January 2011 [83]. SELCO Solar Lights has set up 25 energy service centers in the states of Maharashtra and Gujarat to sell SHSs and offer financing, as well as maintenance services [84]. They sell SHSs through financing agreements with regional rural banks, MFIs and credit cooperatives. Eighty-five percent of the capital cost is covered by a loan, repayable over 5 years at an interest rate of 12–17%. Even 20% costs of the typical SHS of 30 Wp is often an unaffordable obstacle for the bottom-of-the-pyramid market. SELCO has tried to solve this financing issues that most rural households face. It has rallied hard with local financial institutions (such as Grameen Banks, Cooperative Societies, Commercial Banks and MFIs) to provide financing support to these households.

3.1.2.2.3. UNEP financing. A 4-year US$7.6 million program was launched in April 2003 to help accelerate the market for financing SHSs in southern India [85]. The project is a partnership between UNEP Energy Branch, UNEP Risoe Centre (URC), two of India's major banking groups—Canara Bank and Syndicate Bank, and their sponsored Grameen Banks [86]. This program provides a credit

Table 9
Financial Parameters and Central Financial Assistance for SHSs (pre-approved PV models) to be financed by NABARD and MNRE.

Model	Photo voltaic module (Wp)	12 V battery (AH)	Indicative capability of the system lighting load/other loads and operation duration	Indicative cost (INR)	Maximum capital subsidy eligible (INR)	Max. loan amt. (INR) bearing interest at 5%
I	10	10	10 W/4 h	3000	900	1500
II	18	20	10 W/8 h; 20 W/4 h	5400	1620	2700
III	37	40	10 W/12 h; 30 W/4 h	11,100	3330	5550
IV	50	60	20 W/8 h; 40 W/4 h	15,000	4500	7500
V	70	70	20 W/12 h; 30 W/8 h; 50 W/4 h; 60 W/4 h	21,000	6300	10,500
VI	85	120	40 W/8 h	25,500	7650	12,750
VII	100	120	30 W/12 h	30,000	9000	15,000
VIII	120	135	40 W/12 h; 50 W/8 h	36,000	10,800	18,000
IX	150	150	60 W/8 h	45,000	13,500	22,500
X	180	180	50 W/12 h	54,000	16,200	27,000
XI	200	2 × 120	60 W/12 h	60,000	18,000	30,000

Table 10
Financing scheme of MNRE and NABARD.

Sr. No.	Items	Features
1	Borrower contribution	20% of the cost of the project
2	Loan contribution from the Bank	50% of the product cost
3	Interest rate	5% per year on the loan amount only
4	Repayment period	Maximum 5 years
5	Loans security	As per the existing RBI guidelines
6	Capital subsidy	30% of the product cost. Capital subsidy component would be released to the suppliers by the financing Banks only after satisfactory installation and commissioning of the system
7	Period of subsidy	Initially up to March 2013

Table 11
Participating Grameen Banks in the solar loan program.

Canara Bank	Syndicate Bank
Tungabhadra Grameen	Bijapur Grameen
Chitradurga Grameen	Malaprabha Grameen
Sahyadri Grameen	Varada Grameen
Kolar Grameen	Netravathi Grameen

facility to help rural households finance for the purchase of SHSs. Interest rate softening helps them build solar financing portfolios without distorting the credit risk or the existing cash market for SHSs. Table 11 shows the participating Grammen Banks in Canara and Syndicate Banks Solar Home Program. Customers are allowed to access PV system financing from any one of the 2076 participating Canara or Syndicate bank branches. These loans are typically for 18–40 Wp systems costing INR 10,000–25,000 (US$250–600). The loan repayment duration is 5 years with interest rate at 9–15%, with a 15% deposit. Maximum loan ceiling was INR 25,000 (US $600) to prevent the affluent from obtaining large loans for large systems. Banks were initially paid INR 300 (US$7) to establish the loan. This is about 1–3% of the INR 10,000–25,000 loan. Report shows that majority of customers are happy with their vendors and with the level of the Banks' service and loan processing protocols. SHS sales under UNEP loan program in Karnataka and Kerala states as on April 2008 are 18,246 and 19,533, respectively [87].

3.1.2.2.4. Grameen Bank financing scheme. Households of Lala Teekar village of Moradabad district of Uttar Pradesh state used to spend more on buying kerosene for lighting than most on-grid customers. Prathama, a rural bank in Moradabad district of UP state, introduced its microfinancing scheme for procuring SHS [88]. Over 80% households of Lala Teekar village have bought SHSs. The bank has financed over 29,000 home lighting systems in three districts: Rampur, Moradabad and JP Nagar in western Uttar Pradesh under the scheme called Prathama Solar Jyoti. Over 75% households in 21 villages in these districts now depend only on solar energy. Representative case of National and Rural Banks and private organizations providing credit for procuring and installation of solar energy home lighting system is depicted in Table 12 [78,89,90].

Some private enterprises are working with the financial institutions to develop the suitable financial solutions to help rural customers to purchase solar lighting and thermal systems. Although financing from a local bank was available to procure a lighting system, the 25% down payment as stipulated by the Reserve Bank of India (RBI) norms was too steep. Furthermore, nationalized and commercial Banks solar loans can be specifically required to have a minimum annual income of the borrower of INR 30,000–50,000, which is about US$1000/year. As a result, low income group population could not afford the 25% margin money and deprived the access to loan facility.

3.1.2.2.5. Barefoot financing scheme. Barefoot Power Pvt. Ltd, Australia has proposed a financing scheme for MFIs for solar lighting to reach the poorest of the poor who use kerosene the most for [21]. To make these concepts more pro-poor, a one year loan of US$40–50 on a 2.5 Wp 2-LED lamp solar kit is affordable to perhaps most kerosene-using households. MFIs also get marketing commission when partnering with a supplier in addition to interest on the credit amount. The proposed micro-financing scheme is displayed in Table 13.

3.1.2.3. Conclusions. SHSs are currently too expensive for the larger market of lower-income groups and beyond their reach. Consumers are deterred by high upfront cost of SHS and companies poor after-sales maintenance. Without more attractive financing options and inadequate servicing and maintenance of SHSs, the market for SHSs will be confined to a smaller segment. SHS companies can reduce the upfront product cost by developing leasing options, providing various financing options for users, and developing other sources of revenue, such as after-sale service contracts.

Furthermore, the financing of SHSs program seems to be not matured enough in India. For the success of the mission to provide light to the rural population, the SHS program needs strong commitment and policy support to provide finance to rural households. Getting credit from the financial institutions for low

Table 12
National and Rural Banks and private organizations credit scheme for SHS.

Nationalized Bank [89]	(a) Rural Banks (Ref. 90) (b) Prathama Rural Bank (Ref. 88)	Private Organization—SELCO [78,84]
Eligibility: Households in rural/semi-urban/urban centers, small business establishments, hotels, hospitals, restaurants, etc. which have an assured source of income. *Type of Loan*: Medium term loan repayable in installments.	(a) *Rural Banks* *SHS*: Bank finances two standard solar homes systems (SHS): 35 Wp of PV with two fluorescent lights and a socket, and 70 Wp with four lights and a socket. *Cost*: Systems cost US$340 and US$680 respectively, including installation and one year of service.	*Credit system*: Loan through regional rural banks, commercial banks, NGOs and rural farmer cooperatives *Service support*: SELCO helps its customers obtain the necessary credit to purchase solar lighting and thermal systems
Quantum of loan: 75–85% of the project cost	*Loan amount*: loan amount 80% of the total cost. *Down payment*: initial down payment 20%	*Interest rate*: Interest rates are based on the credit source and range from 5% to 14%
Down payment: 15–25% of the project cost		*Down payment*: Customers typically put between 10% and 25% down
Security : (a) Upto a limit of INR50,000/- - Hypothecation of solar energy home lighting system (b) Limit above INR 50,000/-Hypothecation of solar energy home lighting system; and Mortgage of land or collateral security in the form of LIC policy/NSC/Term Deposits. Suitable third party guarantee. *Repayment* – Finance extended to farmers: 5–7 yearly installments along with interest. Finance made to others: Advance to be repaid in monthly installments in 5–7 years. *Disbursement*—directly to the suppliers of solar lighting system after installation of the unit against original invoices, stamped receipts, delivery note duly acknowledged by the borrower. The borrower should confirm to the Bank that he has received the system in good condition and it is working satisfactorily. *Rate of interest*—As prescribed by Head Office for agricultural advances, from time to time.	*Period of Payment*: five years (b) *Prathama Rural Bank purpose*: To provide term loan for installation of the SHS system i.e. Module/panel, Battery, Charge control, lights and fittings *Eligibility*—Individuals such as farmers, traders, professional etc. and institutions *Loan amount*—Unit cost is INR 6000, 12,000 & 18,000 depending upon the Wp. Maximum loan of INR15,000/- can be granted *Down payment* : 15–25% of the total cost *Payment period*: Within 5 years in suitable monthly, quarterly or half yearly installments. 3 months initial moratorium period may be given. Monthly installment of INR 300/-. *Security*—Two coobligants/guarantors	*Credit amount*: 75–90% *Payment period*: Paying the balance over three to 5 years

Table 13
Proposed loan schemes for SHSs.

SHS system size (Wp)	2.5	10	18
SHS system cost INR	1800 (US$40)	5500 (US$123)	9500 (US$212)
Loan capital (85%) INR	1530 (US$34)	4675 (US$104)	8075 (US$179.44)
Loan term (years)	2	2	5
Interest rate per annum (flat) (%)	25.0	25.0	12.0
Annual repayment INR	905 (US$20.11)	2766 (US$61.46)	2240 (US$49.78)
Weekly payment INR	17 (US$00.38)	53 (US$01.18)	43 (US$00.95)
Total repayment INR	1811 (US$40.24)	5532 (US$123)	11,200 (US$249)
Interest paid INR	281(US$06.24)	857 (US$19.04)	3125 (US$69.44)
Marketing/loan administration fee paid to MFI, INR	60 (US$01.33) (3.3% of system cost)	180 (US$04) (3.3% of system cost)	300 (US$06.66) (3.3% of system cost)
# of times fee paid during loan term	1	1	1

margin group of people is extremely difficult task due to cumbersome financial support system. Banks' reluctance in financing SHSs is due to risk factor of payback of loan. Absence of simple credit system and infrastructure to help rural population is hurting the energy poverty alleviation program. Financial barrier is inhibiting the interest to purchase solar lights. The potential growth of this market is significant, but the government's role is critical to the development of clean energy services and technologies for India's rural BoP population.

3.1.3. Indonesia

3.1.3.1. Introduction. The archipelago of Indonesia comprises over 17,000 islands, of which 6000 are inhibited as displayed in Fig. 11. Around 101.2 million population (or 7.2% of the world total population) of Indonesia (total population 237.6 million) are living without modern electricity [91–93]. About 80% of the population (of 101.2 million) is located in rural areas. Currently, 35–40% of households of Indonesia, mainly in rural areas, are not electrified. About 20,960 of the more than 60,000 rural villages are connected to a public electricity grid. Despite Indonesia's quest to raise rural standards of living through electrification, the government recognizes it cannot afford to supply conventional energy sources to rural areas over vast distances. The government seeks to diversify to more economic and renewable alternative energy sources. Indonesia has huge resources of solar energy. Most of areas get a quite intense of solar radiation with the average daily radiation of 4.8 kWh/m^2/day [94,95]. Owing to the abundance of sunlight in most parts of the

country, SHSs had long been recognized as a viable alternative to conventional grid electricity, especially in areas where households were dispersed or on small islands and energy demand was quite low. Solar PV is the quickest option to provide those households with electricity. The use of photovoltaic technology is one of many solutions to provide electricity to rural and remote areas in Indonesia [96].

The first demonstration Photovoltaic Project of 88 SHSs (38 Wp) and 15 street lights in Sukatani, West Java, Indonesia was became operational in December 1988 [97]. The performance of SHS was excellent. However, 45 batteries out of 118 (38.1%) went bad and were replaced after 50 months of installation. The performance analysis of SHS and street light systems in Sukatani after 9 years showed that the villagers have a positive opinion about these systems and are satisfied about the performance [98]. The Sukatani-project stimulated the widespread use of SHS in Indonesia [11,99]. Satisfied with the success of Sukatani-project, the President of Republic of Indonesia announced the project called "The President Aid Project" in the year 1990. In 1991, the Indonesian government initiated the Solar Power for Rural Electrification scheme in villages of Sukatani and Cileles in West Java (Listrik, Tenaga, Surya, Masuk, and Desa), in which 3545 SHS units were successfully deployed in 13 provinces. By the mid-1990s, approximately 20,000 SHS units had been installed throughout the country, mainly through government-funded programs. Generally, 30–60 Wp SHSs are popular in Indonesia.

SELF launched a 100-Household SHS project in the West Java region of Indonesia in 1996 under the auspices of a "State Environmental Initiative" grant program sponsored by the Council of State Governments and US–Asia Environmental Partnership [100]. The World Bank provided a fund of US$118.1 million to the Government of Indonesia during 1997–2003 [101]. About 200,000 systems were to be installed through this project in areas too remote to access existing power grids. However, the project only could manage to install less than 5% of its original targeted sales, or 8054 systems, by its end in 2003. As a consequence, the World Bank decided to close it down at the end of 2000, 15 months ahead of schedule. Lessons leant from project include the importance of creating a properly responsive financial infrastructure, establishing a sustainable SHS supply chain which provides quality products and services, and ensuring strong government support for project development.



Fig. 11. Map of the Indonesia comprising islands.

3.1.3.2. Financing. The SHS project was financied by GEF and co-finaced by World Bank, Government of Indonesia, and other participating Banks. The proposed sustainable financial scheme was consisted of (i) socio-economic status, (ii) the ability and willingness to pay, and (iii) clear and transparent banking schemes. Distribution of PV deployment for free to the rural households, adopted by the Government, was ineffective and not delivering the expected benefits at rural areas. The procurement procedures may be vulnerable for malpractices, leading to deployment of technically substandard SHS. Eva Wulandari discusses various approaches for financing the SHS such as (i) microfinance organizations and rural/commercial banks, and (ii) Direct Sales of SHS through dealers/company—Cash Market [102]. The proposed financing mechanism comprises sharing of credit risk by diversifying the risk and providing credit guarantees. The credit guarantee may be provided by the local people. The salient features of the Credit scheme are:

- Down payment: 25% of the price,
- Loan amounts: IDR (Indonesia Rupee) 1–5 millions,
- Loan maturities: 6 months – 2 years – not longer,
- Interest rate: 24% or higher per annum—to cover collection cost and high risk,
- Collateral: SHS for the company and credit guarantee, and
- Repossess the systems—only cover 50% of the credit loss.

Other financing plans of SHS for different segments of rural population were proposed as displayed in Table 14 [91].

The entrepreneurs were convinced that the only way to sell larger volumes was to offer finance. Local banks (who only ever lent for 2 years) were uninterested. To provide a solution, the company offered its own financing. Once financing was offered only 10% paid cash, the remainder preferring to pay a 25% deposit and enter into a 4 year unsecured loan at market rates (30% interest)—the solar system was considered adequate security. Payments were of the order of US$12 per month for a 50 W system. The entrepreneur had played a key role in the

Table 14
Financing schemes of SHS systems for consumers.

Scheme 1 Under developed area	Scheme 2 Credit installment for 10 years	Scheme 3 Credit installment within 1–3 years (commercial scheme)
1. Government provides SHS, transportation to site and installation. 2. All cost will be paid by government initially. 3. Consumers pay installment after 2 years of installation 4. Technical and financial management at village level. 5. Down payment will be used for the first investment of the management.	1. Use lease and purchase contract for 10 years 2. Consumers pay for the hardware 3. Installation, transportation and interest are paid by Government 4. Local cooperative unit is responsible for technical and financial management 5. The monthly payment is paid to Agency for the Assessment and Application Technology (BPPT).	1. Down payment: 20–30% of total cost 2. Use lease and purchase contract 3. Payment period: 1–4 years 4. Marketing strategy: decided by dealer 5. Interest rate: Local commercial rate 6. Subsidy from GEF: US$2/Wp

development of the World Bank's 1997 Indonesia SHS project, targeting the sale of some 200,000 systems. Regrettably, just as the World Bank project was signed off by the Indonesian Government the Asian economic crisis hit. The cost of modules in local currency quadrupled overnight, sales halted and the business collapsed. Indeed, the micro-financing is clearly beneficial to such a business. However, the experiences in designing the program in Indonesia contributed significantly to the development and success of the World Bank project in other part of the world.

3.1.3.3. Conclusions. Indonesian Government has introduced solar PV systems over 20 years ago for rural electrification. But due to the lack of clear and supportive government policy for PV utilization, there is no progress statistics and other data about PV utilization is hard to find. Not much information about the SHS in Indonesia is available on the website of Ministry of Energy and Mineral Resources (MEMR) [103]. Under the current price of US $500 per unit for a basic 50 Wp SHS, which is used as a standard entry level for rural electrification by the government, around 200,000 households in rural areas receive basic electricity per year [104].

Due to the absence of clear and supportive government policy for PV utilization, it (i) makes hard to predict the Indonesian PV market size, (ii) makes unattractive market for private investors to build either assembling lines or a full manufacturing line of solar cell and panels, and (iii) is obstructing rural electrification program to provide light to currently Indonesia's 35–40% of unelectrified households.

Recently, the initiation of policy making by the government for supporting the use of solar PV gives a positive sign that the government is paying more attention to this resource.

3.1.4. Lao PDR

3.1.4.1. Introduction. The Lao People's Democratic Republic (PDR) with an estimated population of 6.2 million is a landlocked country, bordered by Thailand, Myanmar, China, Vietnam, and Cambodia as displayed in Fig. 12. Development initiatives in Lao PDR are impeded by geographic and demographic conditions: 70% of the country is mountainous and thickly forested, with a highly dispersed population largely living in rural and remote areas, lacking access to basic social infrastructure, communication, transport links, and professional opportunities. Solar energy is considered to be a viable and suitable option for supplying electricity in the larger portions of off-grid to support the rural development. The Lao PDR is situated in a tropical zone, the country has about 300 days of sunshine per year and the annual mean daily global solar radiation in the country is in the range of 4.0.5–5.0 kWh/m²/day, which makes potentially good location for solar energy utilization [105].

The Government of Lao PDR has set a target to electrifying 80% of households by 2015 and 90% by 2020 by extending the electricity grid to rural households, which account for 68% of the total population, while also promoting the off-grid renewable energy throughout the country [106]. Only 8% of rural Lao households were connected to the electricity grid. Isolated small communities make the cost of grid connection per household prohibitively expensive. To achieve rural electrification, the government recognizes that decentralized solutions are required to reach the widely dispersed population. Of the total households connected, 35,000 use off-grid systems such as SHSs or mini-hydro-power plants. Achieving the government's 90% national coverage target by 2020 likely will require at least between a three-to four-times increase in coverage by off-grid solutions over the course of this decade, from around 2.5% share of national households today to 8–10% by 2020.



Fig. 12. Map showing the location of Lao PDR.

Since 1980 PV technology has been applied to domestic electrification, particularly in remote areas through many programs. Recently, the World Bank has approved the loan of US $34.82 million for the rural electrification to increase the access to electricity of rural households [107]. Sunlabob, a private commercial company set up in 2000 and licensed in 2001, has installed more than 10,000 systems in over 500 villages and locations in Laos [108]. It has public private partnerships with various development agencies, such as GTZ, DEG, and IFC.

3.1.4.2. Financing scheme. In Laos PDR, about 74% of the population lives on less than US$2 a day, and cannot afford to pay for installing solar systems due to the high upfront cost. Low internal rate of return on the investment in alternative energy sector is also inhibiting the market development of solar energy and is a major concern for either the public investment or the private sector. Least Developed Country (LDC) and one of the poorest countries in East Asia stigma attached to the Lao PDR are also contributing to the poor investment climate. To crack this nut and address this dilemma, some NGOs have developed an innovative financing concept. Furthermore, the World Bank is providing a soft loan to the Government to finance the SHS program for rural poor households. Two modalities for payment of SHSs such as paying for the panel and fee the service (rental) are popular in Laos.

3.1.4.2.1. Paying for the panel. The Provincial Energy Service Companies (PESCOs) are responsible for the implementation of this project. The payment for the panel scheme gets fund from the Government of Laos PDR which itself receives soft loan from the IDA, Australia AID, GEF, World Bank and Norad. In 2009, PESCOs had provided SHS to more than 200 villages and delivered more than 13,000 units with the grant funding from IDA and AusAID. Recently, the Government has received a grant to deliver an additional 10,000 SHSs under the proposed Rural Electrification Phase II Project supported by IDA, AusAID, GEF, and Norad [109].

SHS systems are available to households through an innovative hire-purchase scheme. Households have a choice of a range of solar PV panel sizes and pay an installation fee (the lowest of which is 136,000 kip (about US$16, $1=KN10,300 (kip)), then lease the system and make monthly payments of 8500–25,500 kip (about US$1–3) over 5 or 10 years. They become the owners of the system at the end of the lease period.

3.1.4.2.2. Fee for service (rental). Unique rental model brings solar power to remote Lao villages. Sunlabob Rural Energy Ltd.,

which has been bringing solar energy to poor rural communities in the Lao PDR on a commercially-viable basis since 2001. It has public–private partnerships with various development agencies, such as GTZ, DEG, and IFC. Sunlabob's success is due to a rental service which avoids upfront costs and direct subsidies.

Sunlabob offers two options:

i. Solar-powered lanterns are rented for prices beginning at 35,000 kip per month (US$3.80), lower than the 36,000–60,000 kip per month (US$4.00–6.60) households typically pay for kerosene for light and much safer and less polluting. After 10 h' use, the lanterns are recharged for a small fee from the village's central solar-power collection facility. All fees go towards maintaining the central solar recharging station.
ii. The equipment is rented to a village-appointed Village Energy Committee, which sub-leases it to households at prices it sets. Rent covers all costs, including replacements and operational servicing costs. In the event of breakdowns, rent payments are suspended until repairs are made. Sunlabob trains Lao franchisees to install solar photovoltaic equipment in their villages and trains local technicians in maintenance. The franchisees act as back-up technical support to the village technicians.

Rental service financing model of Sunlabob is very popular and successful in rural population of Laos.

3.1.4.3. Conclusions. SHS lighting is very important to rural people as it can improve their living conditions, serving light for children, more working hours to promote income generation for women and men during the night, health care, access to information, etc. The financing concept is still in its infancy. Many poorest families find difficulties in obligatory payment. Poor investment climate in Lao PDR is also the hindrance to solar energy market development. Public and private investments and synergy effects are necessary to help to promote a sustainable village system. Integration of livelihood aspects to the energy projects (electricity to generate income or other wellbeing) may be more effective to improve the quality of life and for rural poverty eradication.

3.1.5. Cambodia

3.1.5.1. Introduction. In 2009 about 14.8 million people lived in Cambodia, of which 22% in urban areas. In 2010 only 29% of households had access to the electricity grid in Cambodia. Almost 100% of urban households are electrified (73% of these households are situated in Phnom Penh), but only about 12.3% have access to services in rural areas. In rural Cambodia, about 11 million people (about 79%) live beyond the reach of electric grids [110]. Most villagers rely on one of two sources for lighting: kerosene lamps, which serve nearly half of this off-grid market, or automobile batteries, which villagers use if they have a bit more money and seek energy for lighting, cell phone charging and watching television. Cambodia Socio-Economic Survey (CSES) 2004 shows that 52.9% population use kerosene as a primary lighting source and only 46.2% population use grid electricity/generator/battery for lighting their households [112]. Similarly, less than 19% in the poorest quintile have access to city power, generator or battery as against 82% in the richest quintile as displayed in Fig. 13 [111]. Recently, Ministry of Industry, Mines and Energy (MIME) has set a rural electrification target (i) to provide electricity of some type to all the villages of the Kingdom of Cambodia by the year 2020, (ii) to have access to grid quality electricity to at least 70% of households by the year 2030 [112]. Cambodia receives monthly average solar radiation of 5.5 kWh/m²/d.

The Renewable Energy Action Plan (REAP) was formulated in 2003. Cambodia's REAP 2002–2012 states that 5% of all energy is to be supplied using renewable energy technologies. Main funders are the World Bank, GEF and the Government of Cambodia. Crédit Mutuel Kampuchea (CMK) is funded by the French Development Agency; UNDP-Cambodia manages the GEF small grants program. While the SIDA, Swedish agency, works at policy level about climate change topics in Cambodia. Recently, the World Bank and the Ministry of Energy (MIME/REF project) has provided funds to a supplier (Kamworks and a Chinese Enterprise) in order to supply, deliver and install 12,000 SHS to 7 provinces in Cambodia as displayed in Fig. 14 [112]. Low power photovoltaic (PV) lighting systems in the range 30–50 Wp are increasingly being applied to provide lighting to rural households in developing countries. Table 15 shows the various SHS systems provided by Kamworks Ltd.

The solar technology provided by Kamworks Ltd. is developed as a complete product of solar technology system, i.e. all components are included in one box. For the end-user it is therewith an easy-to-use appliance. Initially, the solar technology systems were sold (including installation, battery and a one year warranty) for.

In Cambodia, several suitable solar products are available for rural households. Financial services are however, a major gap. The banking and microfinance sector is one of the most developed sectors in Cambodia with 27 commercial banks, 6 specialized banks and 20 licensed microfinance institutions [113]. As of end of 2009, 20 licensed MFIs were operating plus additional 26 registered rural credit NGOs were providing microfinance services. Furthermore, around 60 NGO-MFIs, not licensed nor registered, provided informal financial services. Vision Fund (MFI) [114], Yejj Solar (NGO) [115], and Crédit Mutuel Kampuchea (CMK) [116] are already in the solar energy market and also providing finance to procure the SHSs. Other major enterprisers/suppliers of solar home products are International Solar Solutions, Khmer Solar, and Kamworks.

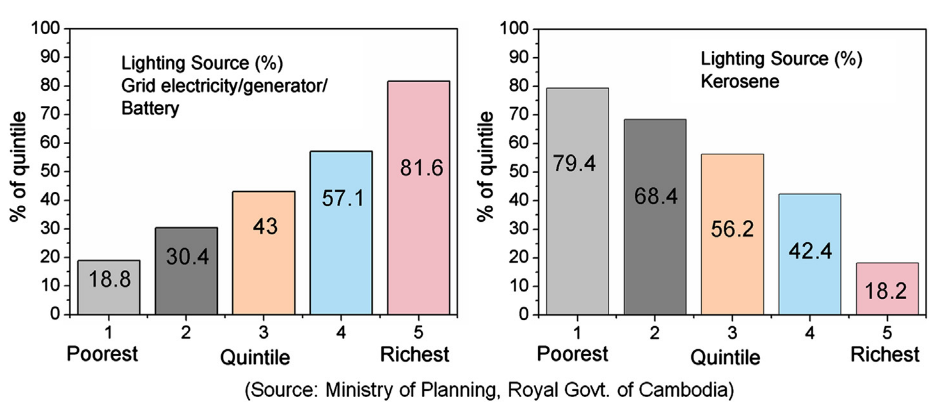


Fig. 13. Quintile of population using grid power/generator/battery and kerosene as primary lighting source.

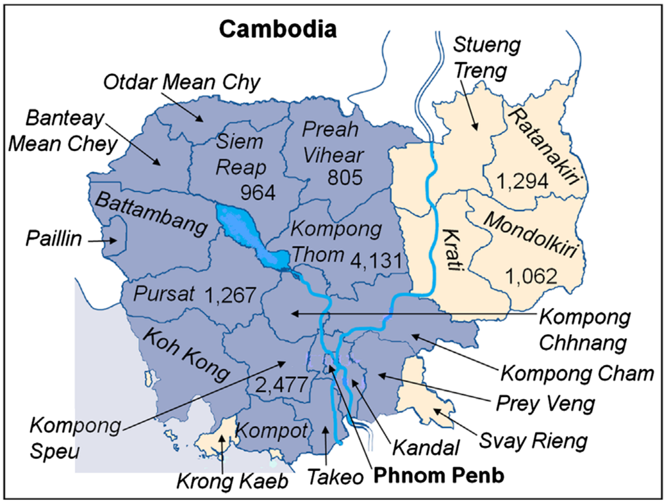


Fig. 14. Locations of installations of 12,000 SHS are planned to be installed at 7 targeted provinces.

Table 15
SHS systems provided by Kamworks Ltd.

Sl. no.	Kamworks Ltd
1	2.5 Wp panel feeding 12 V 2.8 Ah battery, 2 × LED matrix
2	5 Wp panel feeding 12 V 5 Ah battery, 4 × LED matrix
3	10 Wp panel feeding 12 V 17 Ah battery, 2 × LED matrix and 2 fluorescent tubes
4	15 Wp panel feeding 12 V 26 Ah battery, 2 × LED matrix and 2 fluorescent tubes
5	15 Wp panel feeding 12 V 26 Ah battery, 4 × LED tubes
6	Medium SHS (DC, 40 Wp–48 Ah): (US$465)
7	Large SHS (DC, 78 Wp–96 Ah): (US$870)
8	Large+SHS (AC, 78 Wp–96 Ah): (US$990)

Table 16
Microfinancing schemes offered by various MFIs.

MFI	Financing scheme
Vision Fund Cambodia	**Lending methodologies:** Community Bank, Solidarity Group, or Individual **Loan size:** KHR 80,000–KHR 4,000,000, US$20–US$10,000 **Interest rate:** All loans are provided with a competitive and reasonable interest rate. **Repayment mode:** All loans are tailored to best meet the applicants' business cycle and cashflow. **Client eligibility:** *General requirements for loans:* • Age of majority • Good character and background, determined through reference checks • Existing legal businesses or income-generating activities (formal or informal) • Residence at a permanent address • Consent from spouse or household members to access the loan • Realistic and profitable business plan • Ability to share the investment, either in operating their business or by sharing ownership of the assets purchased with the applied loan • Ability to form group guarantee in case of taking loans in the form of a community bank • Ability to provide guarantor(s) with collateral sufficient to guarantee payback of the loan amount
Yejj solar	*Consumer loans: Home lighting* Loan size: US$18–179 Loan period: 6–12 months Interest rate (flat): 30% Monthly payment: US$3.45–17.15
CMK	*Loan amounts*: Start at 40,000 KHR or US$10 Credit is based on payment abilities which are linked with savings at CMK. *Loan period*: Maximum 36 months. *Interest rate*: Varies from 1.5% to 2.5% per month, depending on the loan type. *Repayment*: On a monthly basis and interest calculation is on remaining due capital, using the amortizing balance method.

3.1.5.2. Financing schemes. Vision Fund Cambodia is a licensed medium-sized microfinance institution with a clear social mission to provide financial services to help the poor liberate themselves from poverty [114]. It offers three types of lending methodologies to its clients, namely community bank, solidarity group and individual loan. Yejj solar tech (established in 2001) is a sustainable non-profit organization bringing affordable solar energy solutions to the people of Cambodia. Its goal is to break the negative poverty cycle created by a lack of access to the modern energy services [115]. Yejj is already working on micro-financing for the solar systems. Together with Vision Fund Cambodia and Yejj, they have conducted the pilot study for micro-financing the SHSs. Table 16 shows the microfinancing schemes offered by different MFIs.

In 2004, Crédit Mutuel, 2nd Cooperative Bank in France has set up mutual saving and loan network in Cambodia, called Crédit Mutuel Kampuchea (CMK) micro-finance to promote economic and social development through financial services and solidarity principle [116]. CMK receives financial support from the French Development Agency (AFD) via the French Embassy and French Ministry of Foreign Affairs.

Different business models in operation in Cambodia to finance SHSs technology are:

1. Sales on credit—credit is provided by the solar company,
2. Sale is by the solar company and credit provided by the MFI/Bank,
3. Hire purchase/lease by the Finance Co/Leasing co.,
4. Solar systems technology or SHSs rental, and
5. Manufacturing/assembling/sales and maintaining/finance provisioning by the MFI.

3.1.5.3. Rural electrification fund financing scheme. Rural Electrification Fund (REF) SHS program has been restructured to bulk purchase by REF and installation at rural level for 12,000 households.

1. Rural households repay the cost of the SHS in installments to REF.
2. Period of repayment: 4 years.
3. The local authorities will be responsible to disseminate this SHS units to the rural customers.
4. REF recruits private firm(s) for collection of repayment and maintenance of SHS installed for the rural household customers.
5. Monthly installment: US$5 per month which is less than recharge of old batteries or buys new batteries.

3.1.5.4. Private lenders. Private lenders in Cambodia often charge a high interest rate on the loan. The average interest rate per annum is around 20%. Three-year loan for a US$200 SHS, the interest rate will push the total investment to about US$320.

3.1.5.5. Korea Aid Agency (KOICA) solar power plant in Koh Slar, Kampot Province. Recently, Korea International Cooperation Agency (KOICA) has built a solar power plant (60 kW stand-alone facility not connected to the grid, constructed by BJ Power Co. Ltd., South Korea) in Koh Slar, Kampot Province of Cambodia [117]. Koh Slar is small village of around 320 households built in 2008 by the Cambodian government for retired soldiers and their families and about 110 km (68 miles) southwest of the Cambodian capital of Phnom Penh. Before the opening of solar power plant, the villagers of Koh Slar had no or little access to electricity, making daily duties onerous and entertainment impossible. With the solar power plant, Koh Slar residents can take charged batteries back to their homes to power their TVs and lanterns, and then come back to the power plant to recharge them. The batteries give enough power for a home for 7–10 days. Villagers now have cheaper and more electricity to light up house, use the electric fan, and watch TV as compared to batteries charged with diesel-generated electricity. Battery recharging costs only 25 cents, one-eighth the average cost of getting the same amount of electricity from a diesel-powered plant [118]. However, residents of Koh Slar do not have to pay any fees for recharging the batteries. KOICA covered all these expenses [119].

3.1.5.6. Conclusions. The cost for a SHS in Cambodia ranges from US$200 for a 20-W system to US$600 for an 80-W one. Although expenses on automobile battery use vary from family to family, depending on the battery size and recharging frequency, the investment in solar home systems usually takes 3 years to pay back. SHSs are becoming more cost competitive as diesel fuel costs escalate. Still, many rural populations find it tough to make the switch over to solar energy as they cannot afford the upfront investment. Although the lending scheme helps villagers deal with the upfront investment, it is far from perfect.

3.2. Sub-Saharan Africa

In an enterprise survey in sub-Saharan Africa continent [120], the electricity was cited as the top elemental constraint on enterprise growth in 11 of the 30 countries surveyed, and second in nine more countries, compared with issues as critical to enterprise success as access to finance and macro-economic stability. Map of the continental Africa is shown in Fig. 15. The reliability of grid electricity is also questionable. The power outages occur quite frequently in Africa and almost every day of the year in Nigeria. Table 17 shows the number of days in a year power outages in 2009 [120–122]. Africa generates only about 4% of the world's electricity, three-quarters of which is used by South Africa and northern Africa. Sub-Saharan Africa has the world's lowest electricity access rate, at only 26 per cent [123]. The rural electricity access rate in Africa was only 25.8% and that in sub-Saharan Africa was 14.2% in 2009 [124]. The total population in Africa without access to electricity in 2009 was about 587 million [73]. With no substantial changes in current policies and practices, the total number of people without access to electricity in sub-Saharan Africa will increase to 691 million by 2030 [19].

For Africa's poorest families, lighting is often the most expensive item in their budget, typically accounting for 10–15% of the total household income. The energy poor in Africa spend about US $17 billion a year on fuel-based lighting sources. Beyond household use, commercial use of fuel-based lighting can have even more acute economic impacts. Fishermen on Lake Victoria in Kenya, for example, often spend half of their income for the kerosene they use to fish at night. But many African countries are making strides to put fuel-based power behind them.

Lighting Africa, a joint IFC and World Bank program, is helping to develop commercial off-grid lighting markets in Sub-Saharan Africa as part of the World Bank Group's wider efforts to improve access to energy. Lighting Africa has piloted its approach in Kenya and Ghana and is now expanding its activities to Tanzania, Ethiopia, Senegal and Mali. South Africa and Kenya have some of the highest documented installed capacities of solar PV systems that stand at over 11,000 and 3600 kWp, respectively [125]. Unfortunately, poor households have not benefited much from solar PV systems due to the high upfront costs and the absence of affordable finance scheme.

Earlier report also showed that majority of the rural poor in Sub-Saharan Africa (about 80%) could not afford even the smallest

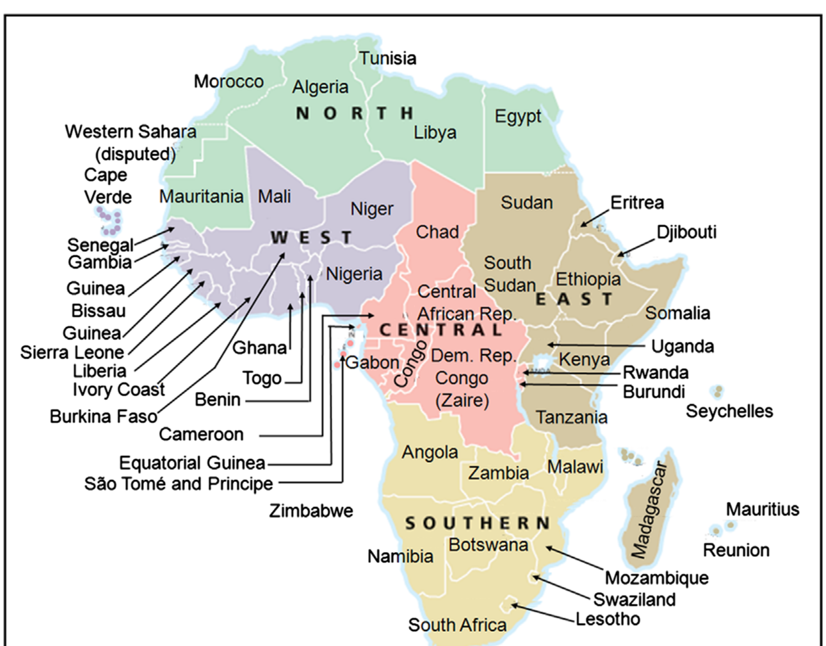


Fig. 15. Map of the continental Africa.

Table 17
Number of days in year grid power outages in some countries in Africa.

Country	Number of days per year power outages		
	Vijaya Ramachandran, Alan Gelb, and Manju Kedia Shah, 2009 [120]	Enterprise surveys—World Bank Group (2007–2008) http://www.enterprisesurveys.org [121])	Africa Infrastructure Knowledge Program www.infrastructureafrica.org/ [122]
Nigeria	365	47	321 (2005)
Gambia	235	82	
Tanzania	120	68	63.1 (2007)
Kenya	80	87	40.6 (2009)
Senegal	30	43	141 (2005)
Mali	20	20	52.2 (2007)
South Africa	25	7	
Ghana		61	116.4 (2005)
Ethiopia		79	44.2 (2008)

18 Wp PV systems although the micro-finance and subsidy driven PV distribution programs were accessible [126].

3.2.1. Kenya

3.2.1.1. Introduction. The population of Kenya in 2011 was estimated at 40 million. About 50% of the population lives on less than US$2 per day with about three-quarters of those living in rural areas [127]. Only 28.9% of the population was connected to electricity till 30 June 2011, [128]. Over 77% people do not have electricity connections. Currently, only about 5% of rural and 51% of the urban population have access to electricity. Fig. 16 shows the map of Kenya. Over 79% of the total households and 87% of rural households in Kenya use kerosene-based lamps as the main source of lighting [129]. It is virtually impossible to connect every Kenyan household to the national grid system by 2030 due to the huge capital investments needed [130]. The scattered nature of rural settlements makes grid connection unattainable in the near future. Recently, Abdullah and Markandya have reported that the high connection payment for the grid electricity (870 KSh/month) as well as PV solar lighting (700 KSh/month) is one major issue, impeding the rural electrification program [131]. A need to establish long-term schemes to finance the initial or upfront costs of electric connection/PV system especially for those on low or intermittent incomes has been proposed.

Rural Electrification Authority (REA), created by the Government of Kenya in July 2007 to fast-track the rural electrification program, sets a target in the Vision 2030 document to achieve 100% connectivity to all [128]. Table 18 shows the rural electrification short, medium and long term targets in the vision 2030 document.

Kenya's current power sector fuel mix is comprised of hydropower (52%), diesel (22%), geothermal (10%), thermal (5%), and the balance (11%) of wind, gas, emergency plants and co-generation assets [132]. The current installed capacity of the Kenyan grid is 1473 MW. Its electricity mix is dominated by the hydro generation and thus highly vulnerable to weather conditions such as periods of drought and climate change [133]. Kenya's electricity grid is largely dependent on the expensive hydropower and only 5.2% of rural households, mostly relatively well-to-do, use grid electricity. Solar is comparatively low-cost alternative, especially for families whose poverty puts grid-based electricity out of reach. Solar energy offers a huge power potential for the nation as solar energy in Kenya could potentially generate up to three times the current daily national grid requirements. Kenya receives daily insolation of 4–6 kWh/m^2. Presently, solar energy is extensively used for drying and to some extent, for heating and lighting in Kenya. The REA has entered into a partnership with the IFC to spearhead a new initiative called "Lighting Africa".

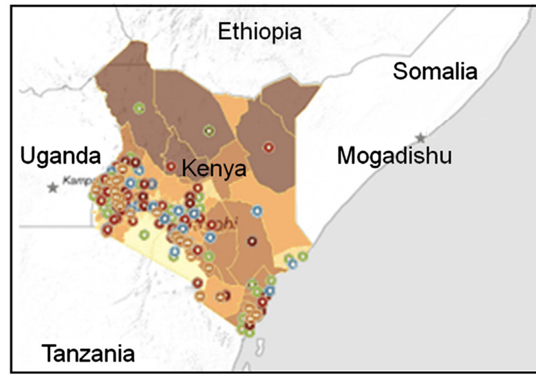


Fig. 16. Map of Kenya.

Table 18
Rural connectivity target (cumulative).

Year	Target of rural electrification connectivity
2012–2016 (short term)	At least 27%.
2012–2022 (medium term)	50%
2012–2030 (long term)	100%

Table 19
SHS units installation target.

Year	Target of SHS units (cumulative)
2012–2016 (short term)	100,000
2012–2022 (medium term)	200,000
2012–2030 (long term)	300,000

Over 300,000 solar PV systems for household use (lighting, radio or television) have been installed since the mid-1980s with the private sector playing a major role [134]. The Government is undertaking efforts to provide PV lightings to public institutions in Arid and Semi-Arid Lands where there is no access to the grid. It has planned to promote the installation of at least 100,000 units of solar PV home solar systems as substitute for kerosene in lighting rural areas, poor semi-urban and urban settlements (short term goal 2012–2016) (draft paper 2012). Table 19 illustrates the target set by the Government of Kenya to install SHS units in rural areas. Long term goal (2012–2030) is to promote installation of at least 300,000 units of solar PV home systems [128]. However, no central catalyzing agency to set the technical specifications for the solar equipments and certification exists so that only standard SHS system will be delivered to the customers [135]. Kenyan SHS owners and vendors make all technology selection decisions.

3.2.1.2. Financing schemes. The solar campaign targets 13.5 million people, both households and small businesses, in rural Kenya. The project is good for people who are living in rural area. However, the high prices of the components of solar power systems are one of the major obstacles to the mainstream adoption of alternative energy for households. The total upfront cost of a solar PV system (size less than 50 Wp) at the household level is about US$ 621 [131]. Many families can afford to spend 20–50 shillings a day on kerosene, but are struggling to find 2000 shillings for a solar lamp (1 US$ = 80 KSh). Finance agencies offer credit for SHS

Table 20
Repay of credit without interest (amount of loan=2000 KSh)

Daily installment (shillings)	No. of days to repay the loan
50	40
20	100

Table 21
Financing scheme of SHS of K-rep and SACCOs.

	K-rep	Cooperative Bank and SACCOs
Down payment	No	25% of loan
Interest rate	18.5%. Current interest rate 20.8%	About 12%
Fees	0.5% (insurance fee)+1% set up fee (passbook, KSh 100 +membership, KSh 150)	Loan is only for SACCOs registered members
Loan term	Maximum 2 years	Maximum 2 years
Loan amount	Loan offered for 20, 40, and 60 Wp SHS systems ranging from KSh 32,000 to 68,000	Loan offered only for 60 Wp SHS
	Includes installation cost+pre-paid maintenance costs for 2 years	Loan amount includes installation cost+pre-paid maintenance costs for 2 years
Conditions	Savings: - Minimum KSh 100/ month - > 10% of loan	Registered member of SACCOs

systems allowing more rural Kenyans to buy them. Under this arrangement, a salaried employee signs up the contact with a hire purchase company that automatically deducts monthly installment of repay from his or her salary. Interest rates, which run 40% a year or more, are factored into the price. To attract more customers, the short duration repay scheme for the credit of 2000 shillings without any interest is also implemented as shown in Table 20. Although the initial costs of a solar kit are high compared to kerosene lamps, the overall cost of the solar kits is lower as there are no operational costs. However, these efforts are not enough for the sustainable development of SHS systems market.

Programs to charge zero interest have been used several times to stimulate sales in developed countries such as on car loans. Identical programs for other household durable equipment have been in place over the years. However, no such program exists in Kenya. Banks and credit cooperatives are reluctant to enter the photovoltaic business because of the risk factor of repayment of credit. The real obstacle seems to be credit risk which could be minimized by a non-onerous credit enforcement mechanism that is supported by the local governmental authorities.

In Kenya, prices vary between US$10 and US$93 for the solar kits depending on their capacity as compared to the monthly average of US$10 spent by each household on kerosene. When compared to SHSs and automotive-type batteries, the community-based schemes such as mini-hydropower hold promise for 'deepening' access to electricity for low-income rural households. The average energy cost of hydropower (US$0.10/kWh) is orders of magnitude cheaper than the energy from a typical (20 Wp crystalline) SHS (US$1.0/kWh) or auto-type (12 V; 50 Ah) batteries (US $7.62/kWh) [136]. In order to make the solar kits readily available and affordable to the rural poor, starting of a microfinance business model which allows poor village folks to make small payments over time until they have fully paid off the kits, is essential.

Acceptance of SHS systems can be greatly enhanced if poor populations are provided with access to financing and credit to pay for the SHS systems. In Kenya, as of June 2009, the banking sector comprised of 43 commercial banks, 2 mortgage finance companies, and 123 foreign exchange bureaus. In addition, about 29 microfinancing institutions are working in Kenya [137]. However in reality, the poor have limited options for financing the purchase of modern energy services. Only about 10% of Kenyans have access to formal financial services [134]. SREP fund is available only for big alternative projects such as hybrid mini-grid systems, solar water heating, small hydropower development, scaling-up improved biomass cook stoves in institutions, and development of 400 MW of geothermal in Kenya [129]. Recent survey shows that commercial Banks charge very high interest rate ranging from 15% to 38.9%, leaving small borrowers with the highest loan burden [138]. Jamii Bora has the interest rate of 38.9%, followed by K-Rep at 20.8%, Imperial Bank (20.5%), Family Bank (16.5%), UBA (15.9%) and Equity Bank (15.7%). These banks mainly lend in smaller amounts to small and marginal income customers. The loan size (80% of the loans) of Jamii Bora in 2008 was less than 10,000 KSh (approximately US$125). While banks have been charging customers at rates of between 24% and 32%, Savings and credit cooperatives (SACCOs) have kept their rates low at between 2% and 12% [139]. Jamii Bora provides a loan of 8000 KSh for buying the SHS that covers the cost panel, battery and 15 W bulbs. SACCOs are a vital source of financial services in Kenya. Table 21 shows the financing scheme for SHS of K-rep and SACCOs in 2000 [140]. The Cooperative Bank of Kenya, Ltd. (CBK) identifies SACCO partner for providing loan for SHS to customers. Recently, CBK has also increased its lending rates from 12% to 17% [141]. The Imperial Bank offers the aid in the purchase of designated assets such as motor vehicle, equipment, machinery and industrial plants over a period of time, ranging from 12 to 36 months [142].

Earlier, Muramati SACCOs undertook the Muramati SHSs project under the Photovoltaic Market Transformation Initiative (PVMTI) an initiative of the IFC and the GEF. Muramati SACCOs was to provide loans to members to enable them to afford the purchase of a solar home system [143].

Rural customers have to qualify the requirements of MIs, commercial Banks to get the credit for energy products as displayed in Table 22 [143]. In many cases, poor rural customers are unable to satisfy requirements of FIs and deprived of benefits of modern lighting.

3.2.1.3. Conclusions. Loans are a very common financing vehicle to reduce the upfront cost of energy products. The financing needs for SHS systems are loud and require long loan tenure. However, no dedicated and affordable fund from the Financing Institutions for the purchase of SHSs for poor customers is allocated and available. The absence of strong political commitment, support from the government and affordable and flexible financing scheme are hindering the progress and deployment of SHSs for home lighting in rural areas. No interest business model may be the obstacle for growth of SHS market and also for the sustainable development of SHS business model.

3.2.2. Ghana

3.2.2.1. Introduction. The population of Ghana is about 25,241,998 as on July 2012 [144]. About 72% of Ghanaians live in communities with access to grid electricity [145]. Fig. 17 shows the percent of population having access to grid electricity in different regions of Ghana. More than 48% of communities or 83% of rural households are not connected to grid power and most are unlikely to have access to grid electricity in the foreseeable future due to their geographic locations. On average 46% population of the total is without access to electricity in 2008 [146]. Ghana initiated the

Table 22
Requirements for getting loan from MFs and Banks.

MFs	Banks	SACCOs
– Established credit history – Own a business – Personal loans – Must have saved before Borrowing – No group backing – Operation of an account – -Dependent on business cash flow	– Account holder – Cash flow analysis – -Review of business records – Collateral which could be: Household or business assets, Log books, Title deeds	– Account holder of SACCOs – Cash flow analysis – Review of business records – Collateral which could be: Household or business assets, Log books, Title deeds, Leveraging of shares (loans are a multiple of shares held) – Members guarantee loans

National Electrification Scheme (NES) in 1990 with the aim to provide electricity to rural off-grid population. Recently, Government of Ghana announced the scheme of universal access of electricity to all by 2020 [147]. The policy is to provide the decentralized off-grid renewable energy based solutions such as SHSs until such a time that it becomes economically feasible to extend grid electricity. Government sets the target to increase the current renewable reliance from 0.01% to 10% by 2020.

Ghana receives enormous solar energy resource spread across the entire country. Daily solar irradiation level ranges from 4 to 6 kWh/m^2. Fig. 18 shows the annual global horizontal solar irradiation map of Ghana [148]. Areas of highest irradiation levels are spread across the entire northern belt which represents over 60% of the total national land mass. The annual sunshine duration ranges between 1800 and 3000 h offering very high potential for grid connected and off-grid applications. Consequently, Ghana is the ideal location to make use of solar PV, especially in the rural areas. The solar-home-system between 14 Wp up to 100 Wp are popular in Ghana for home lighting.

Over 6000 solar systems with an installed capacity of 3.2 MW have been installed in the country mainly for off-grid applications [145]. Earlier, Government of Ghana, Ministry of Mines and Energy and the GEF through the UNDP program with technical support from the National Renewable Laboratory (NREL) of the US Department of Energy initiated the project in East Mamprusi District to provide electric services to 13 off-grid communities on a sustainable and affordable basis (1999–2003) [145]. About 1.600 Solar Home Systems have been installed under this program. This fee was charged in US dollars (US$) based on the cost of the systems, and was initially the cedi (Ghanaian currency) equivalent of 5 US$ [149]. Table 23 shows the financing scheme of SHS [150]. In 1999, US$10.00 (¢25,000.00) per month on domestic energy use such as kerosene, candles, dry cell batteries, charging of automotive batteries for black and white TVs etc.

3.2.2.2. Financing SHSs. Ghana has 27 commercial banks, 135 rural and community banks (RCBs), 48 non-bank finance companies (finance house, savings and loans institutions, leasing companies,), and 45 MFIs (provisional approved) with the Bank of Ghana as a regulator [151]. The ARB Apex Bank Limited is the umbrella body of all rural and community Banks in Ghana and provides loans to rural population. MFIs are an important part of the nation's economic development as they offer credit to the poor and encourage more people to become entrepreneurs and set up small businesses. Table 24 shows representative financing

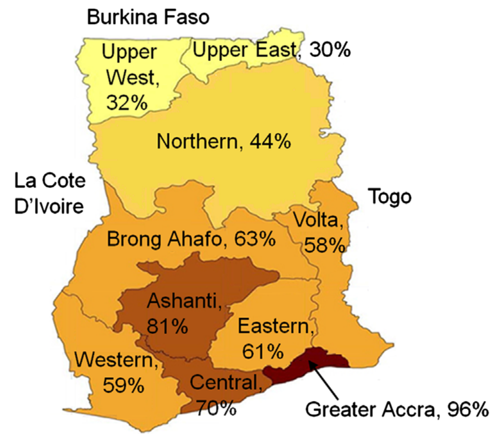


Fig. 17. Access to electricity based on population percentage. National average is 66.72%. (Source: Ministry of Energy).

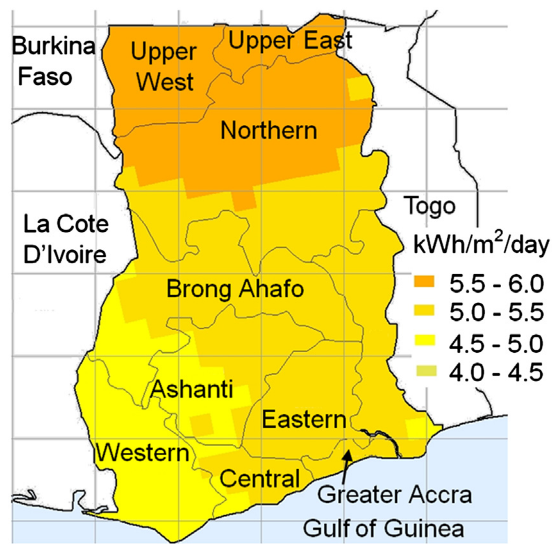


Fig. 18. Annual global horizontal solar irradiation map of Ghana.

Table 23
Financing scheme of SHS.

Solar home system	100 Wp	50 Wp
Initial connection fee	US$30 (160,000 Chedis)	US$20 (100,000 Chedis)
Monthly service fee	US$3 (15,000 Chedis)	US$2 (10,000 Chedis)

schemes of rural and commercial Banks such as North Volta Rural Bank [152], Barclys Bank [153], Cal Bank [154], and Ghana Commercial Bank Ltd. [155]. In reality, no commercial bank has a portfolio dedicated to RETs for rural poor. Furthermore, their stringent requirements are difficult to meet for the poor population.

In recent years, Ministry of Energy, Government of Ghana reported that 2317 households have been benefited from the stimulus facility since its inception in 2009 with the North Volta Rural Bank being one of the anchor banks. Ecobank (Gh) Ltd. is also providing finance under the microfinance and poverty alleviation scheme to under banked and the unbanked poor, otherwise have no access to finance. Ecobank also acts as banker to MFIs [156].

3.2.2.3. Global partnership on output aid (GPOBA) program. In October 2008, the World Bank has signed a grant agreement

Table 24
Financing scheme of rural and commercial Banks.

North Volta Rural Bank	Barclays Bank (Gh) Ltd.	Cal Bank Ltd.	Ghana Commercial Bank Ltd.
Finance to meet the needs of rural, small-Current. *Interest rates*: Between 22% and 29% per year. *Repayment of loan*: At predefined intervals daily, weekly, fortnightly or monthly.	*Interest rate*: competitive *Repayment*: one month after you draw on the loan. Fixed monthly payments	*Loan scheme*: 1. Applicant must have been in permanent employment for 6 months. 2. Introductory Letter from Employers/ Company Undertaking. 3. Current Pay Slip. 4. Personal Identification—Passport/ Voter's ID Card/Driver's License. 5. One Passport Picture. 6. Proof of Residence—Utility Bill/ Tenancy Agreement. 7. Company Guarantee/Provident Fund	*Loan for*: Education, Agriculture, Health, Sports and the Environment *Repayment:* Short term, 12 months payable by monthly equal installments Long term: over a 3–5-year period with negotiable repayment terms *Interest rate*: For 36 months 25% per year *Requirements*: Address proof, Identification Proof, Residential status (own house or tenant), Educational status, Government payroll/staff number, Employer's undertaking

with the Government for 4.35 million dollars to support the program, which would increase poor households' access to electricity through the SHSs and solar lanterns in rural areas of Ghana [157]. The project's objective is to increase electricity access to about 15,000 poor rural households in remote regions of Ghana by subsidizing the installation of SHSs. About 90,000 rural populations where 60% of the population earn less than one dollar a day and the power grid will not arrive for 10 years are likely to get benefit of solar power under a GPOBA aid. Ghana's ARP Apex Bank is the lead bank to implement this program [158]. The salient features of the financing scheme are:

(1) Affordable solar PV systems for poor rural customers by subsidizing approximately 50% of the costs.
(2) Repayment terms of up to 3 years.
(3) The participating rural banks refinance 80% of loan amounts from the GPOBA soft credit.

3.2.2.4. NGOs. The Christian Rural Aid Network (CRAN) energy project at Hohoe is providing 144 remote communities in Northern Volta with solar lighting products [159]. Women and Youth Survival Foundation Program (WAYSFOP), a local organization is partnering CRAN in the solar project to sell 20,000 lighting systems through microloan facility to off-grid remote communities.

3.2.2.5. Private sector. Private trader Deng Ghana reported that the solar prices range from US$530 for a 14 Wp system to US$1470 for a 100 Wp system in 2007. As per his business model, most customers pay cash on installation, although reliable customers may pay two-thirds on installation and the remainder within 3 months [160]. By 2009, a total of 1200 PV systems installed and 7000 solar lanterns supplied.

3.2.2.6. Conclusions. The poverty level of the rural people, the lack of funding and the inadequacy of the Rural Electrification levy have been the main challenges of Ghana's rural electrification programs. In conclusion, no flexible and affordable financing schemes for SHSs for the poor population exist. Individuals have the perception that PV systems are "inferior", and that by installing PV systems, the communities have been prevented from acquiring the "real thing" in the form of grid connection.

3.2.3. Tanzania

3.2.3.1. Introduction. Estimated population of Tanzania is about 43,601,796 as on July 2012 [161]. In 2008, only an estimated 12% of Tanzanians had access to electricity, mostly in towns. Of the rural people, only 1% had access to electricity [162]. About 19% of 40-million plus Tanzanians live under US$1.0 per day. In 2012, only 2% of the rural populations has access to the electricity in contrast to 37% in urban areas (see Fig. 19) [163]. Modern energy services to poor have so far received little attention in Tanzania. On average only 10% of the country's population have access to the electricity [164]. Recent Ministry of Energy and Minerals data shows the national electricity connectivity is about 14% [165,166]. The rural off-grid households in 2009 were estimated to be 5.1 million [167]. Fig. 20 displays the nationwide electrification status (percentage of population having access to electricity) as per Household Budget Survey of 2001 [168]. Government has set a target to increase the access to electricity from 14.5% (2011) to 30% by June 2016 [169]. The population which is not connected to the grid electricity depends on wood fuels as their main source of energy for cooking and kerosene for lighting. For lighting, kerosene, oil or gas lamp was practically the only energy source (96%) [170]. Notable exceptions to this were Zanzibar/ Pemba and Kilimanjaro where 13% of the households reported to use electricity for lighting. The World Bank estimates that the grid extension prices vary from US$ 6340/km in densely populated regions to US$ 19,070/km in regions with dispersed population [171]. Therefore, the grid electrification of rural areas in Tanzania could be hard to achieve in a short time due to the dispersed nature of rural settlements in most of the regions (high investment and low return). Providing grid electricity in all rural areas may be a long term policy which may take many years to fulfill. Furthermore, the grid electricity connection charges in Tanzania ranges from US$270 to US$1957 per connection, about a half to four times national per capita GDP and may be one of the major causes of low electrification rates (14% at national level and only 2% in rural areas) [172]. The lack of connection subsidy or other financing schemes could make the access to grid electricity unaffordable.

The main challenge of the energy sector is to provide modern energy services to rural population of Tanzania. The National Energy Policy (NEP) which drives development of energy sector was launched in 2003. The Government of Tanzania has set up the Rural Energy Agency (REA), autonomous body under the Ministry of Energy and Minerals, to handle rural electrification programs. So far REA has provided electricity to 11 district headquarters and six commercial centers. It has immediate plans to supply power to another 41 rural areas. In Tanzania, major source of electricity is from hydropower. However, other renewable energy resources such as wind, biomass, and solar are also used to produce electricity. The government has an ambitious program to increase the new and renewable energy share to the energy mix (biofuel, solar, wind) to reach 14% by 2015 to reduce the dependence on hydropower generation [169].

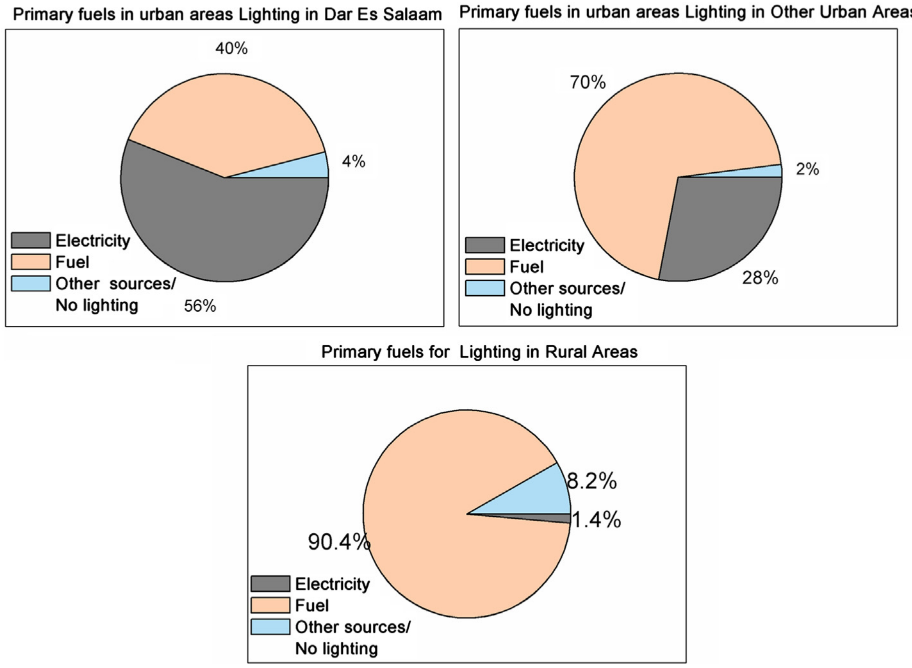


Fig. 19. Rural and urban population using grid electricity and other fuels for lighting.

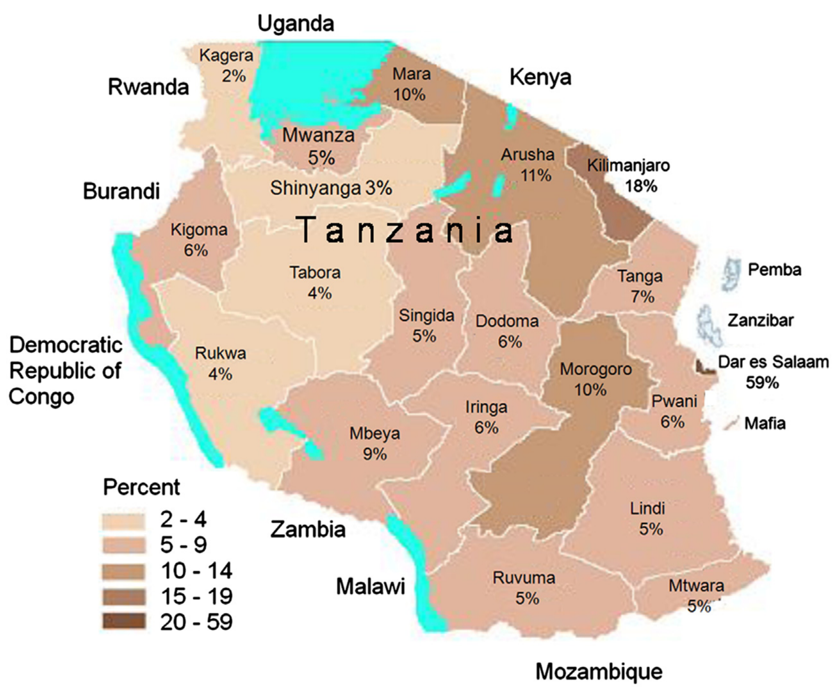


Fig. 20. Nationwide energy situation in Tanzania.

The country average annual solar radiation levels are said to range between 4.2 and 5 kWh/m^2 per day [173]. The use of solar electricity seems to be an attractive alternative as the country enjoys the abundant sunlight. Earlier, Masoud Dauda studied the feasibility of adoption of renewable energy technologies such as Solar PV systems in rural households and the role of such technologies on sustainable energy use and rural development in Tanzania [174]. The results showed that if initial costs are affordable, solar PV systems have a potential to be adopted by rural households.

Tanzania has also implemented the World Solar Program (WSP) from 1996 to 2005 through UNDP, SIDA and World Bank with the main focus on village solar electrification and small island solar electrification. Table 25 shows the solar energy project to be implemented [175].

In addition, local administration, community centers, villagers (such as district education officer for Hai District have distributed solar lights to families through their local schools, community centre at Chole Island; the Chole Mjini Trust Fund installed an IT system powered by solar power system; villagers in Uhafiwa, Mufindi district, and Iringa, received a brand new solar installation on their health dispensary on 10 June 2011; Imalinyi Health Dispensary 30 km from Njombe town in southern Tanzania received solar installation funded by contributions

Table 25
Solar energy projects to be implemented.

	Name of the project	Region of implementation
1	Solar PV installation in rural community	Sengerema, Geita and Chato
2	Revolving Loan Funds for rural lighting technologies for provision of LED technology solar lanterns	Sumbawange, Nkansi, Mpanda (all in Rukwa Region), Mbeya, Mbarali, Chunya, Mbozi, Rungwe, Kyela, Ileje (all in Mbeya Region), Iringa, Kilolo, Mufindi, Njombe, Makete and Ludewa (all in Iringa Region), Mbinga, Namtumbo, Tunduru, and Songea (all in Ruvuma Region)
3	Access to solar energy powered lighting to rural population using the existing trade channel "Mali Kauli" credit system	Bagamoyo District
4	Solar Lighting For Rural Tanzania	Musoma, Ngerengere(Morogoro rural)
5	Sustainable Rural Credit for Solar Lighting systems	Singida Rural Manyoni and Iramba
6	Lighting Rural Dispensaries- Solar PV Installation	Mbinga and Tunduru Districts
7	Sustainable Solar Market Packages (SSMP) Project	Launched in April 2010 to cover nine wards and 80 villages in Sumbawanga district. Approximately, 8,000 PV systems will be installed for private utilization while public facilities will receive 285 PV systems.

from villagers) are engaged in providing solar energy to rural population [176].

GTZ survey reports that the SHS market in Tanzania is poorly developed [167]. PV SHS in Tanzania are mostly purchased by high-end consumers (prosperous farmers, urban-based consumers with families in rural areas) due to very high up-front costs. The capacity of consumers to buy entire systems and pay for installation services are constrained, therefore, the market for installers is also constrained. The off-grid SHS market includes government, NGO and private sector institutions. Mostly, donors and missionary groups have dominated this market. Earlier, Mwihava reported that the majority of the poor rural households could afford the expenses for Renewable Energy Technologies, if they find some kind of financing from FIs since available household income can hardly afford cash payment for the desired energy technologies [177].

3.2.3.2. Financing. Tanzania has formal FIs such as 32 licensed commercial banks, 17 private banks, as on 26 July 2012 [178]. They operate under the guidance of the Banking and Financial Institutions Act of 1991, and are closely monitored and regulated by the Bank of Tanzania. While the informal category comprises about 5300 SACCOs, 50 savings and credit associations (SACAs), and 45 community based organizations (CBOs), 53 NGOs, and village cooperative banks (VICOBAs) [136]. The Tanzania Association of Microfinance Institutions (TAMFI), local microfinance network, has approximately 48 member institutions as of January 2012 [179]. Small number of National Microfinance Bank (NMB) loans and SACCOs loans mostly to teacher members are available [180].

3.2.3.2.1. Rural energy fund. The Rural Energy Fund (REF) was established by The Rural Energy Act No. 8, 2005 for the purpose of providing grants to qualified project developers [181] and became operational in October 2007. The REA has been co-financing grid extension projects implemented by the state-owned utility TANESCO through connection charge subsidization. The Fund also provides resources for co-financing investments in innovative pilot and demonstration projects and applications for renewable energy when development partners make special purpose funds available for that purpose. The sources of income for the fund consist of monies as may be provided:

(i) by Government, in an annual budgetary allocation,
(ii) as contributions from international financial organizations, multilateral and bilateral agencies and other development partners,
(iii) from levies of up to five percent (5%) on the commercial generation of electricity to the national grid; as fees in respect of programs, publications, seminars, consultancy services and other services provided by the REA,
(iv) as development partners' contributions to special purpose funds for rural energy, and
(v) as interest or return on investments.

A Trust Agent (currently Tanzania Investment Bank—TIB) is responsible for disbursement of grant payments from the fund and ensuring that any pre-conditions set by the Board for making a grant payment are met by developers.

3.2.3.2.2. Loan from financing institutions. In Promotion of Renewable Energy in Tanzania (PRET) program (2005–2007) (collaborative program between Tanzania and German Government), the Government facilitates and supports private sector led growth of the rural energy market by linking financing, solar energy enterprises, and service for consumers. Under the commercially driven solar financing model, MFIs provide loans for buying SHSs.

Major players for wholesalers of solar PV panels and accessories in Dar es Salaam are Solatek, Chloride Exide, BP Solar, Rex Investments, Zara Solar and Umeme Jua Limited (UJL).

3.2.3.2.3. E+Co finance. Solar Company B, E+Co portfolio company, installs, maintains SHSs (14–80 Wp) for residential and institutional customers. In 2007, E+Co provided a US$ 50,000 loan to the company to purchase its inventory. The company sells on a cash basis directly to residential and institutional customers. Retail prices range from US$225 to US$650 for household SHS, and US $1400 for institutional systems. MFIs are still underdeveloped in Tanzania. These are usually private sector entities with specific visions and business approaches.

3.2.3.2.4. Camco model. Camco focuses on private sector involvement, driven by successfully established farmer or worker cooperatives, corporations, and companies providing solar PV products on a wholesale basis [182]. Under this model, Tanzania's REA provides a small 20% subsidy for each solar set-up system while the farmer will pay the remaining 80% (a 20% deposit with the remaining amount being paid off over the following 3 years).

Thousands of teachers in Tanzania live in rural areas without electricity. They can be targeted to form Cluster Groups for SHS loans since through their salaries they have access to a SACCOs making them perfect microfinance clients.

3.2.3.2.5. Zara Solar Ltd., Tanzania financing scheme. Zara Solar, Mwanza provides high quality, affordable PV systems in Northern Tanzania (see Fig. 20). Mwanza, with a population of around 717,000, is the largest city in the north of Tanzania. The population of the whole Mwanza region is about 3.7 million. The technology used by Zara Solar is standard solar PV equipment. The most popular system for homes uses a 14 Wp amorphous silicon solar panel, a lead-acid battery of 25–50 Ah and two compact fluorescent lights, which can be used for about 3 h each night. Most domestic users buy systems in the 14–60 Wp range, while systems of 100 Wp and above are usually bought by institutions, and may

include an inverter for powering mains devices such as televisions. Popular PV systems marketed by Zara are displayed in Table 26.

At present most customers pay outright for the systems. However, Zara Solar has recently started selling through SACCOs, and hopes to provide micro-credit facilities to consumers in future.

3.2.3.2.6. Umeme Jua Limited. Umeme Jua provides access to electricity for rural households in Tanzania through Solar PV. Company targets small SHSs (< 20 Wp) for poor customers. As of November 2006, it has installed more than 5000 systems. In Morogoro and Iringa Region, company has made available loan from the MFIs and solar energy loan scheme of SACCOs.

Financing scheme:

(1) Flexibility of security: e.g. no collateral required, only proof of house ownership via community leader.
(2) Monthly payment should not exceed US$15.
(3) Down Payment should not exceed US$50.
(4) Flexibility of monthly payment (or every 3 months US$50 instead of monthly payment).
(5) Marketing of solar system and finance scheme should be under the same umbrella.
(6) Collection of money done by MFI.

3.2.3.3. Conclusions. Very limited financing options for poor families or businesses to procure solar PV systems are available. Investors should be encouraged to invest in the development of alternative sources of energy and emphasis on the utilization of local resources to ensure security and continuity of energy supplies and to reduce dependence on hydro-power. Solar energy should be promoted in both urban and rural areas. Although, Government policy in general is supportive of solar power, the market penetration of solar systems still remains relatively limited for a number of reasons, including up-front costs (most retailers sell on a cash basis only), excessive margins, lack of credit, and inconsistent quality (including imitation solar products). The Microfinance industry in Tanzania is relatively young. Except loans from some MFIs, the market for solar PV equipment is almost entirely based upon cash sales. Due to Tanzania's modest per capita income, many people may end up with poor quality least expensive PV systems. Therefore, Tanzania has to do more to improve the flexible and affordable financing for solar energy products to rural and urban poor population.

3.2.4. Ethiopia

3.2.4.1. Introduction. The total population was estimated to be 85,237,338 in 2010 [183], while CIA World Fact Book estimates the population around 93,815,992 as on July 2012 [184]. In 2007, the total number of households was about 15,634,304 [185]. Fig. 21 shows the percent of regional households using grid electricity for lighting in 2007 [186]. At the country level, only about 13% of the total households use electricity as a source of lighting. More than 90% of rural households are without electricity.

Table 26
Zara photovoltaic system (£1 = 2500 TSh (Tanzanian Shillings) in 2007).

	System	Cost
1	14 Wp PV system, with Lead- acid battery, charge controller and two fluorescent lights. Installation charges (additional 10%)	234,000 TSh (£94), 23,400 TSh (£9.4)
2.	70 Wp PV system with Lead- acid battery, charge controller and two fluorescent lights. Installation charges (additional 10%)	964,000 TSh (£390), 964,00 TSh (£39.0)

Present exchange rate £1 = 2515.49 TSh as on September 2012.

Significant gap exists between the power supply of urban and rural populations: only 2% of the rural but 86% of the urban residents has access to electricity [187] as displayed in Fig. 22. About 15% of the total rural population lives in 922 towns having more than 2000 households and the remaining 85% live in scattered rural villages and have very remote chance to get electricity through the national grid [188]. Therefore, renewable stand-alone system based lighting to electrify the rural houses seems to be the most appropriate option. Consequently, Ethiopian Electric Power Corporation (EEPCo) launched the Universal Electrification Access Program (UEAP) in 2005. The UEAP envisages improving electricity access from 15% to about 50% over a period of 5 years. The program also aims at raising per capita electricity consumption from the level of 24 kWh per year in 2007 to 128 kWh by 2015 [187]. The Ethiopian Government under proclamation no. 317/2003 also established Rural Electrification Fund (REF) to implement the off-grid private sector-led rural electrification [189]. The off-grid rural electrification program is done by private investors, including rural communities, cooperatives and small and medium enterprises (SMEs).

Ethiopia is well endowed with renewable energy sources. The solar radiation values vary from a minimum 4.55 kWh/m^2/day in July to a maximum 5.55 kWh/m^2/day in March as displayed in Fig. 23 [190]. The average daily solar radiation is around 5.2 kWh/m^2/day. Earlier, the Government of Ethiopia (GoE) with the technical as well as financial assistance from the Italian government had executed a PV-based rural electrification project in the mid-1980s. However, this donor program proved unsuccessful and unsustainable. Later, Ethiopia's largest solar project was initiated in 1997 and located in the village of Rema, 150 miles north of the capital city, Addis Ababa, was funded by international aid groups. Every house in Rema is now powered by electricity, a rarity for Ethiopia. About 10,081 rural have been benefited from the distribution of SHSs and 238 rural health stations and first cycle schools have been provided with solar electric power by 2009/10 [191]. About 150,000 households will be provided solar home system units by 2014–2015 through the UEAP.

3.2.4.2. Financing scheme. The existing national plan of the Ethiopian Government targets 75% grid access rate by 2015 and to reach 100% of electricity access before 2030. To fulfill this target, the rural electrification program is implemented using on-grid and off-grid electric expansion programs. The FIs of Ethiopia are

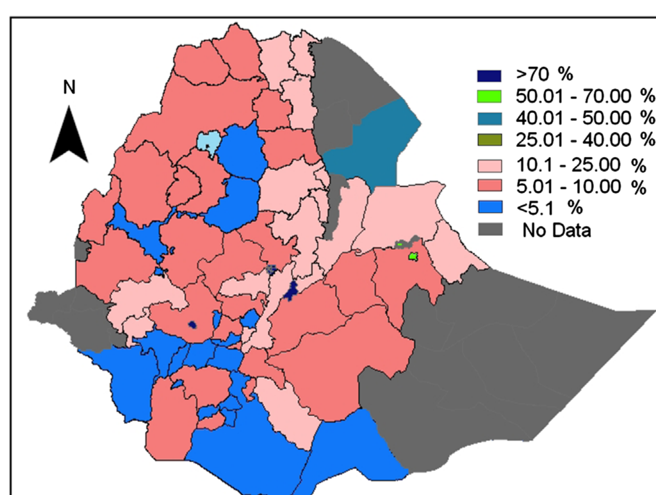


Fig. 21. Percent of regional households using electricity for lighting in 2007 (Source: Central Statistical Agency of Ethiopia).

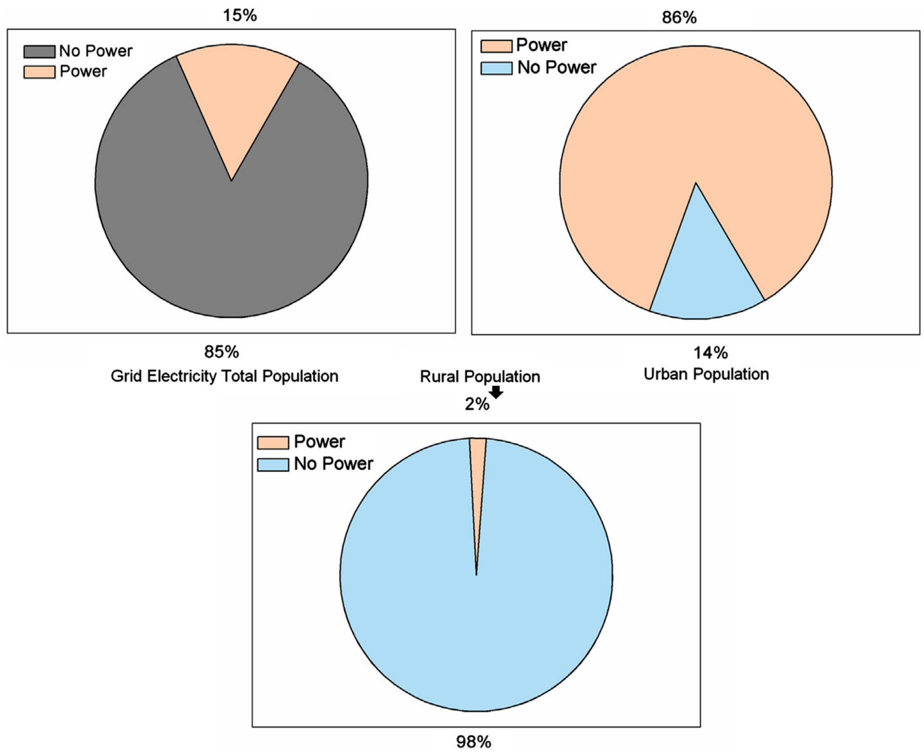


Fig. 22. Percent of total, urban and rural populations having access to grid electricity.

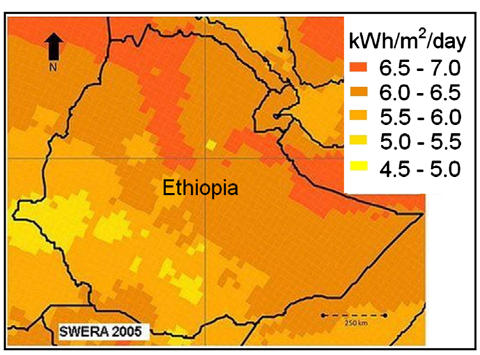


Fig. 23. Solar insolation map of Ethiopia (in kWh/m^2/day) (Source: modified SWERA 2005).

comprised of 18 commercial Banks, 14 insurance companies, and 19 MFIs [192]. National Bank of Ethiopia acts as a supervisory and regulatory Bank. The grid expansion has been, and will continue to be, financed largely from the pubic treasury and from multilateral development banks, mainly AfDB, World Bank, and other bilateral funds such as the Kuwait Fund [193]. The off-grid rural electrification program is done by IDA and private donors. Representative MFIS providing microloans for various activities in rural Ethiopia are shown in Table 27 [194]. Most of these rural MFIs receive grants from the international organizations. As per the National Bank of Ethiopia's regulations, the interest rate to be charged on loans and advances extended by a MFI is determined by the MFI; single borrower loan limit is Birr five thousand (maximum); and repayment of loans is 12 months (maximum), however, can be extended the repayment period depending performance of the enterprise. However, no loan solely for SHSs and RETs in their service/product portfolio is available. Many MFIs in Ethiopia are not aware about the RETs such as SHS, biogas technology and hence not willing to take any credit risk [195]. Furthermore, stringent requirements such as collateral and credit history requirements exclude poorer borrowers. Therefore, financing model of SHSs in Ethiopia is either fee for service, microcredit or free distribution. Pay for solar system in cash is out of question as many rural populations do not afford. From the data available, fee for service scheme for financing of SHS seems to be most sustainable business model in Ethiopia.

3.2.4.3. REEEP to fund rural energy access in Ethiopia. The Renewable Energy and Energy Efficiency Partnership (REEEP) and Fund for International Development (OFID) have recently announced three new sustainable energy projects in Ethiopia. World Vision has been awarded over US$144,000 for a project in Ethiopia, which will develop local cooperatives in two low-income rural districts to finance the distribution of energy-efficient stoves and solar-powered lights [196]. World Vision provides the training to local cooperatives and government agencies in book keeping, technology repair and stove production.The project aims to provide 3000 households with access to solar lighting and energy efficient stoves and start 30 cooperative societies.

3.2.4.4. Solar energy foundation. Solar energy foundation (SEF) (2004), established in Ethiopia in 2006 by Harald Schützeichel (German Businessman), has installed over 2200 small solar systems in two villages (Rema and Rema ena Dire) that are off the electricity grid by 2009 and plan to install further 8500 units elsewhere in the country (see Fig. 24). SHS module consists of a solar module with 10 Wp, 2–4 lamps (1 W LED lamps with 25 lm or 3 W CFL lamps with up to 90 lm), and mobile phone charger. The villagers pay a low monthly fee (about US$1) (fee for service business model) [197]. This amount covers the maintenance and repairs to keep it running. The village committee manages payments and employs nine local people as fee collectors. Each SHS costs 3000 ETB (about 167€, September 2009), including manufacturing and installation. The capital cost of the systems

Table 27
MicroFinancing Institutions providing microloans for various activities in Rural Ethiopia

MFIs	Wisdom Micro-financing Institution (S.C.)	Addis Credit and Saving S.C	Amhara Credit and Saving Institution (ACSI)	Gasha Micro Financing S.C.	Poverty Eradication and Community Empowerment (PEACE)
Loan types	Agricultural, Businesses, Enterprise	Individual, Cooperative, Community-Based Organizations	Installment loan; End-term loan; Package loan; Input loan.	Non-seasonal Group Loan, Seasonal Group Loan, Individual Loan	Agricultural loan, Non-agricultural loan
Interest rate	12.5%+2% service charge annual	10%+3% service charge	Installment: 15% End-term: 18% Package: 18% Input: 15%	13%+3% annual service charge	15% Non-Agriculture, 18% Agricultural loan
Loan amount (Birr)	5000	2000–5000	5000	200–10,000 (group loan), 1500–10,000 (Individual loan)	1000–5000 (agricultural), 850–2500 (non-agricultural (business) loan)
Loan period (months)	12 months	7–24 months	3–12 months	12 months (non-seasonal group and individual loan), 4 months (seasonal group loan)	3–12 months
Eligibility criteria	*Existing business*—with more than 6 months experience; *Regular saver*; *Permanent resident* in the operational area; *Willingness* to be organized in a solidarity group	*Permanent* residence in the City of Addis Ababa; *Unemployed* youth and women; *Willingness* and full commitment to be engaged in income generating activities; *Willingness* to be organized into credit group and take loans through group *collateral*; Above 18 years of age (working age)	*Potential clients* between 18 and 59 years of age and economically active; *Potential clients-* Poorest of the poor, owning not more than an ox or an asset of its equivalent; *Need to* be credit worthy, with good reputation among the community; *Business plan*—Includes the availability of market for the product/ service loan is requested for; *Willingness* to be a member of credit group and abide by the bylaws of the group; *Willing to save* some part of his/her business income at ACSI.	*Working poor* with business experience and sound start-up business; *Physically* fit and healthy for the business; *Residences* of specific Kebeles with ID Cards *Good Character* Reference; *Age between* 18 and 60 years; *Willingness* to accept the operational modalities of the Institution; *Without* indebtedness to other financial sources;	*Productive poor* who is not a full time employee of others (government and formal private sector organizations); *members of formally* established associations and groups; *willingness to* save money regularly; *permanent residence in the* village; *No outstanding* loan balances with other financial service providers; *willingness* and commitment to co-guarantee other group members; *without record* of misconduct and misbehavior; *Repayment Record* of previous loan from other NGOs—Not less than 95%.
Collateral needed	Group guarantee/collateral	Group collateral	Group collateral (installment loan)	Group collateral for seasonal and non-seasonal loans and salaried persons for individual loans	Group guarantee

Exchange rate 1US$ = 17.645 ETB (Ethiopian Birr) as on 12 June 2012.

installed in Rema and its neighboring village of Rema ena Dire were financed by donor funds. However, households must pay a monthly fee of between 10 and 14 ETB (0.66€ and 0.78€ in September 2009) depending on the number of lamps in their system. The new contract for service will be signed after successful finishing their 5-year agreement to use the SHSs. Solar energy foundation also created the revolving fund since 2009 to finance the SHS systems.

3.2.4.5. World Bank. Recently, Ethiopia has awarded 16 million US dollar project to provide solar powered electricity to 25,000 households in rural parts of the country [198]. Under this project, 26.5% of the households in Oromia region (Arsi Province along with portions of the Bale, Harerge, Illubabor, Kefa, Shewa, Sidamo, and Welega provinces), 24.9% in Amhara (Gonder, Gojam and portion of Shewa) and Tigray regions and 24.6% in Southern Regional state receive SHSs (see Fig. 24).

3.2.4.6. Conclusions. The major thrust of the Government is to provide grid electricity to all by 2030. The off-grid rural electrification is left to the private investors and donors. Such donor-driven projects may prove to be unsuccessful or unsustainable. No credit from the FIs or subsidy from the Government for SHS is available. Investor's lack of interest due to poor return on the investment and risk factor of doing business with rural population may be the cause of non-availability of loans for SHS. Fee for service model seems to be the most appropriate financing scheme for SHS in Ethiopia due to low purchasing/low repaying power of rural population. Sale and forget model will not work at the rural level. It is necessary to provide maintenance and service. Best trade-off between social service and financial sustainability should be balanced.

4. Best practices of financing SHSs

4.1. Asia

SHS program is well received in rural areas of Bangladesh as an economically viable solution for providing electricity where the national grid is difficult or expensive to extend. Two types of



Fig. 24. Most successful solar home system lighting project in Rema and its neighboring villages.

payment schemes for the use of SHS, (i) fee for service model executed by the REB, and (ii) ownership model (or micro-credit system) which is handled by IDCOL through its POs, are practiced in Bangladesh. A fixed monthly fee for the use of SHS installed on their roofs is charged to households. The PV system remains at the ownership of government. The fee for service model is popular in some regions where people hope that the national grid is going to expand in these regions in future and grid current will be available to users. The permanent ownership model through micro-credit system is more popular in regions where the land is separated from main-land by lot of rivers. The loan amount limited to 80% of the total cost of SHS is made available to households through the IDCOL. The loan repayment duration varies from 3 to 5 years with affordable monthly installments.

In India, about 289 million rural people do not have access to the energy needed for lighting. Therefore, efforts are being made to improve the quality of life for rural poor by providing the sustainable and clean lighting. MNRE provides a CFA for buying SHS up to 30% (limited to INR 81) per Wp for general areas and for special category states/North-East states up to 90% (limited to INR 243) per Wp. SELCO Solar Company, India offers financing as well as maintenance services to rural population for the promotion of off-grid renewable energy technologies (RETs). Grameen Banks, Cooperative Societies, and MFIs are offering microfinancing scheme for procuring solar home lighting system in different part of the country. The loan repayment duration varies over 3–5 years at an interest rate of 12–17%.

Around 101.2 million population of Indonesia (total population 237.6 million) are living without modern electricity and 80% of 101.2 million population is located in rural areas. Most of the SHS projects in Indonesia are through government-funded programs. No steps are initiated to create a properly responsive financial infrastructure and establish a sustainable SHS supply chain which provides quality products and services. The entrepreneurs are convinced that the only way to make sustainable SHS program is to offer affordable mincrofinance to rural population.

In Lao PDR, about 70% of the country is mountainous and thickly forested, with a highly dispersed population largely living in rural and remote areas. Solar energy is most viable and suitable option for supplying electricity in the larger portions of off-grid to support the rural development. The SHS systems are available to households through an innovative hire-purchase scheme (lease SHS system model). After making the monthly payments (about US$1–3) over 5 or 10 years, customers become the owners of the system at the end of the lease period. Sunlabob Rural Energy Ltd. has developed a financing concept of fee for service (rental) model for bringing the solar energy to poor rural communities on a commercially-viable basis since 2001.

In rural Cambodia, about 11 million people live beyond the reach of electric grids. In Cambodia, several rural credit NGOs are providing microfinance services for procuring SHSs. Under the Rural Electrification Fund (REF) SHS program, rural households repay the cost of the SHS in installments to REF at affordable monthly charge. Private lenders in Cambodia also provides loan for buying SHSs often at a high average interest rate of 20% per annum. Recently, Korea International Cooperation Agency (KOICA) has built a solar power plant (60 kW stand-alone facility not connected to the grid) for charging batteries in Koh Slar, Kampot Province of Cambodia. They are not charging any fees for recharging the batteries.

4.2. Africa

The IEA (2010) estimates that about 589 million people in Africa live without access to electricity [3]. Africa's non-electrified population is expected to grow from 110 million households to 120 million households by 2015 [2]. Overall the electrification rate in sub-Saharan Africa is around 30% (60% urban, 14% rural) [199]. African grid expansion is failing to keep pace with population growth. Off-grid solutions can effectively complement grid electrification efforts. Solar technologies provide the alternative to sustainable development and life-changing improvements.

In Kenya, over 77% people do not have electricity connections and only about 5% of rural and 51% of the urban population has access to electricity. Government is promoting the installation solar PV home solar systems as a substitute for kerosene in lighting rural areas, poor semi-urban and urban settlements. Due to high upfront cost of SHS, many families have to depend on the suitable financing scheme. Some finance agencies offer credit for SHS systems to salaried employees. Under this arrangement, employee signs up the contract with a hire purchase company that automatically deducts monthly installment of repay from his or her salary. Interest rates are high which run 40% a year or more. However, the common poor people have limited options or no options for financing the purchase of modern energy services. Commercial Banks charge very high interest rate ranging from 38.9% to 15%, leaving small borrowers with the highest loan burden. Indeed, poor rural household are deprived of benefits of modern lighting.

In Ghana, more than 48% of communities or 83% of rural households are unlikely to have access to grid electricity in the foreseeable future due to their geographic locations. Ministry of Mines and Energy, Government of Ghana, has initiated the project in East Mamprusi District and installed SHSs under this program. Users of SHS pay monthly fee of US$5. Rural and commercial Banks, and MFIs also provide financing for procuring SHSs, but their stringent requirements are difficult to meet for poor population. Ghana's ARP Apex Bank provides affordable SHSs loan for poor rural customers by subsidizing approximately 50% of the costs. Women and Youth Survival Foundation Program (WAYSFOP) NGO is making available microloan facility to off-grid remote communities. Private traders sale SHSs on cash to most customers. Recently, they are also providing some affordable installments for payment to reliable customers.

In Tanzania, only 2% of the rural populations have access to electricity in 2012. Recent Ministry of Energy and Minerals data shows that on average only 14% of the country's population have

access to electricity. Kerosene, oil or gas lamp is their main source for illumination. Tanzanian Government is focusing on village solar electrification and small island solar electrification through the grants provided by international financial institutions. NGOs and private sector institutions are also providing SHS to rural population through fee for service system as the consumers have limited capacity to buy entire systems and pay for installation services. Under the micro-credit system, MFIs provide loans for SHSs. SACCOs also gives loans mostly to teacher members for buying SHSs. Private traders have made finance available from the MFIs and solar energy loan scheme of SACCOs to their customers for SHSs installation.

In Ethiopia, only about 13% of the total households use electricity as a source of lighting. More than 90% of rural households are without electricity. The Ethiopian Government established Rural Electrification Fund (REF) to implement the off-grid rural electrification program through private investors, rural communities, cooperatives and Small and Medium Enterprises (SMEs). MFIs receive microloans from the grants provided by IDAs and private donors for various activities in Rural Ethiopia. MFIs determine the interest rate to be charged on loans, limit of loan amount, and the repayment period. But, many poorer borrowers are excluded from the scheme due to stringent requirements such as collateral and credit history requirements. Fee for service scheme for buying SHS system is most sustainable business model and widely accepted in Ethiopia. Solar Energy Foundation (SEF) has adopted this model for SHSs. Villagers pay a very low monthly fee of about US$1 which covers the maintenance and repair costs also to keep it running. This Foundation has also created the revolving fund to finance the SHS systems.

5. Conclusions

It is not realistic that all of the 1.4 billion people without electricity will receive a reliable grid connection. The amount of investment needed to achieve universal energy access by 2030 was estimated to be between US$35 and US$40 billion a year [72,200]. Even if the electricity is available, the pertinent issue is whether the poor population can afford it. Could the connection charges be affordable? Could the monthly fee be affordable? Low-income households in developing countries are faced with serious questions of affordability. Substantial improvements in supply of modern energy are possible using decentralized technologies. SHSs with LED lamps are most suitable and robust option for the rural electrification. However, financing SHS is a major hurdle due to high initial capital costs of solar systems that create a strong liquidity barrier in rural markets, with merge household incomes.

The World Bank and other donors are convinced that the PV SHS market could be run on a commercial basis. The liquidity barrier is overcome with various instruments like capital subsidies and micro-loans. There are number of ways to apply available financial resources to make modern energy services more affordable to low-income families by addressing the investment costs or the recurring costs.

Currently SHS are used mostly by the middle and high income families, whereas the poor are still unable to afford it. Different solutions are thinkable, e.g. in the short term the initial investment can be decreased through the use of smaller SHS system and/or a higher grant. Fee-for service and micro-credit (ownership) models of financing to extend off-grid solar to rural population have been widely used. Fee for service model is popular in some part, particularly sub-Saharan Africa, due to unaffordable finance scheme and insistence of collateral. In fee for service model, the SHS remains at the ownership of energy provider and customer pays monthly fixed fee for service. While in Asia, permanent ownership model through the micro-credit system is more popular. Energy provider is responsible for maintenance of the systems during the period of loan (2–3 years) after which additional warranty may be purchased by the customer. However, it is argued that both models of financing SHS are not benefiting much to the poor population. Many poor people cannot handle conventional finance plan, which require fixed payments regardless of their income that month.

Furthermore, rural customers are different from urban. Customers in remote villages could not be treated at par as access to information, technical assistance and knowledge, communication mode, other infrastructure are beyond their reach. Could SHSs be treated like any other commodity products? Merely sold and forgot business model practiced in urban areas may not be suitable to rural population as far as SHSs are concerned. Urban based RETs product suppliers are unable to cater the needs of rural clients. It is recommended to indentify and motivate rural RET product suppliers to fulfill the requirements of rural customers. Failing to indentify rural suppliers for rural customers, the millennium goal to provide lighting to by all 2030 will be difficult to realize. Robust SHS unit with a strong after sale service network would be the most successful business model (i.e. service business model) in rural areas. Sale and forget, no training or orientation, no service or maintenance will be a failure business model as customers are totally from a very different stratum of the society.

Transparent documentation on cost, affordable tariffs and subsidy components, no political motivation in solar energy program, continuous monitoring and evaluation procedures, maintenance and emphasis on responsive after sales services are important ingredients for the success of the SHS lighting program for poor. For the poor, affordability has three dimensions: total cost, up-front price, and payment flexibility. Solar power comes in a panel that gives around 15–20 years of light and power but the poor cannot afford the 20-year investment upfront. Why has the poor to invest for 20 years of light at the beginning? While, the urban population are paying monthly tariff of electricity used. For the poorest who are not qualified or afford loan from the MFIs, the One-Stop-Shop Model is displayed in Fig. 25. Single SHS energy company provides the standardized SHSs at an affordable monthly fee (may be 5–7 years), installation and maintenance of SHS, after sale services during the recovery period of the initial investment made by the energy provider. After the complete recovery of the initial investment, the customer becomes the owner of the SHS and the energy company ensures the guarantee of energy supply and maintenance of SHS at a comparatively low monthly fee. The program may be funded by providing the credit to the RETs and SHSs providers from the MFIs, FIs, solar NGOs, and social investment portfolio of the companies or from philanthropists. For the micro-credit customer, the One-Stop-Shop model based on a single micro-energy provider who provides the services of an MFI, supply of standardized SHSs, and after sale energy Service Company is essential as displayed in Fig. 26. This model ensures microfinance (various financing options), installation (solar home and other micro-energy systems), maintenance, after sale service, and guarantee of energy supply with an affordable monthly fee even after the payment of complete loan. After-sales service contracts will improve product quality, build customer loyalty, and serve as a new revenue stream for SHS companies. In conclusion, success of SHSs depends on the extent to which it can fulfill the needs of the end users and able to provide grid quality electricity, which will also motivate users to invest money in SHS systems.

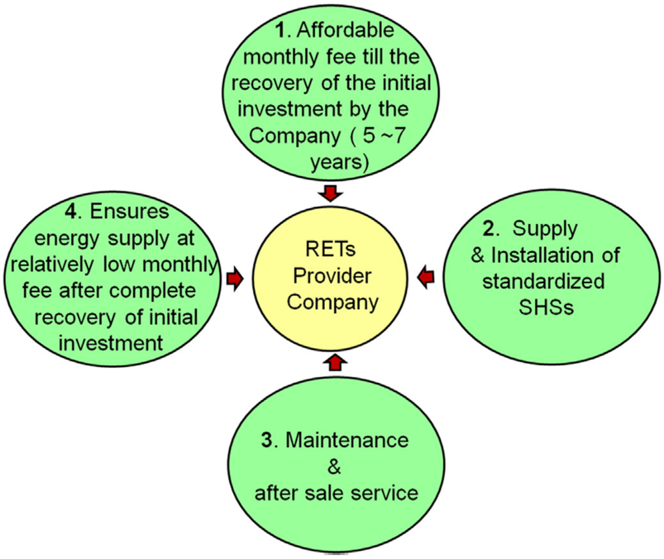


Fig. 25. One-Stop-Shop Model for fee for service SHS energy provider for rural population.

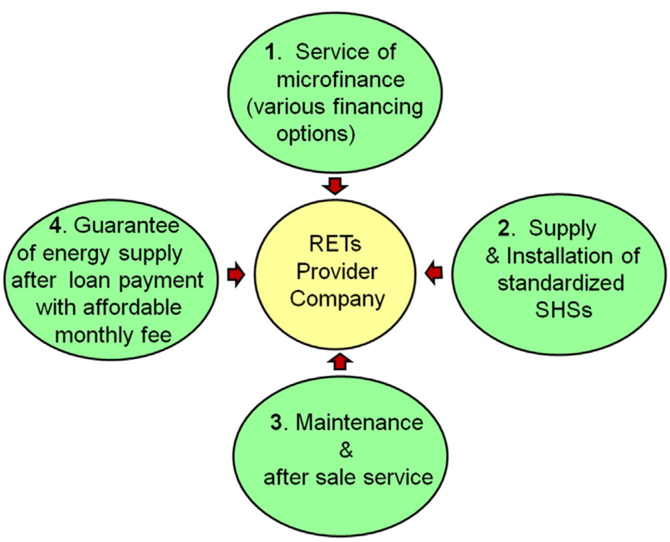


Fig. 26. One-Stop-Shop Model for micro-credit system SHS energy provider for rural population.

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